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Climate Change Management Department

Zimbabwe Climate Change Vulnerability Assessment

An indicator-based report

Acknowledgements

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Executive Summary

Climate change is now a reality across the world and as is such is being incorporated developmental plans of almost all countries. For effective mainstreaming of climate change into developmental plans, there is need to understand the different vulnerabilities that exist across different sectors of the economy. In this report, the vulnerability of different sectors to climate change is presented which forms the basis for developing adaptation options to mitigate the associated impacts. Although there are several definitions of vulnerability, this report is based on the IPCC (2007) definition and framework. According to the IPCC, vulnerability is the extent to which a natural or social system is susceptible to sustaining damage from climate change. Vulnerability therefore is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. This report therefore is based on the vulnerability resulting from the determinants of exposure, sensitivity and adaptive capacity. Exposure and sensitivity which determined the potential climate impact in this case was characterised by the probability of drought and floods since these are the two main climatic hazards identified by stakeholders to affect the country. Finally the adaptive capacity which ultimately shaped the community vulnerability after taking into consideration the potential impact was defined by poverty, dependency on rainfed agriculture, household head characteristics and prevalence of chronic conditions (diseases) among households. These were the four dominant adaptive capacity factors extracted from an initial 23 socioeconomic parameters (to be discussed later) considered.

The main findings of this work are that drought and flood are the main climate hazard that impact livelihoods in the country. These were mainly buffered by a determined combined magnitude of poverty, dependency on rainfed agriculture, household head characteristics and prevalence of chronic conditions (diseases) among households combination that shaped the adaptive capacity. Hence the different levels of sensitivity and adaptive capacity combine to produce varying levels of vulnerability which were calculated at district scale in the country. Based on the vulnerability identified in different parts of the country, sectors specific impacts were determined. When considered against selected future climate change scenarios, these impacts should then form the main basis on which adaptation options are be developed to enhance resilience to climate change.

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List of Acronyms

CMIP5	Coupled Model Intercomparison Project Phase 5
COP	Conference of Parties
CORDEX	COordinated Downscaling Experiment
CRU	Climate Research Unit
GCM	Global Climate Model
GHGs	Green House Gases
GIS	Geographic Information System
GoZ	Government of Zimbabwe
IPCC	Intergovernmental Panel on Climate Change
NDC	Nationally Determined Contribution
ITCZ	Intertropical Convergence Zone
NAP	National Adaptation Planning
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
UNESCO	United Nations Educational, Scientific and Cultural Organization
ZIMSTAT	Zimbabwe National Statistics Agency
ZNCVA	Zimbabwe National Climate Vulnerability Assessment
ZINWA	Zimbabwe National Water Authority

CHAPTER 1: INTRODUCTION

1.0 Background

The Government of Zimbabwe received financial support from the Green Climate Fund (GCF) and in collaboration with the United Nations Environmental Programme (UNEP) are implementing the project "*Building Capacity to Advance National Adaptation Planning Process in Zimbabwe (2019- 2021)*". The project aims to support the country's National Adaptation Planning process by facilitating adaptation activities under the United Nations Framework Convention on Climate Change (UNFCCC). However, to formulate locally relevant adaptation plans and actions in different parts of the country, sector specific vulnerability assessments are required to guide the selection of adaptation options. This is meant to make sure that relevant adaptation options are implemented to build resilience of local communities to climate change. To achieve this, a team of climate change adaptation experts was commissioned to first carry out detailed climate change vulnerability assessment across selected sectors in Zimbabwe and develop a system to prioritise and appraise adaptation options across selected sectors.

Purpose of report

The purpose of this report is to present results of climate change vulnerability assessment for Zimbabwe based on current and future climate change scenarios in support of the NAP process. The report details how climate change vulnerability was accomplished and the implications of the findings to adaptation.

Structure of report

The background and conceptual framework of vulnerability assessment is presented in chapter 1. The technical approach and methodology followed in carrying out climate change vulnerability is presented in chapter 2. Chapter 3 presents results of vulnerability assessment at provincial level while chapter 4 presents sector specific impacts of climate change and their implication to adaptation.

1.1 Introduction

Zimbabwe is vulnerable to climate change and just like most parts of the world is witnessing increasing temperatures and high rainfall variability, changes in the frequency and intensity of extreme weather events and shifting of intra-seasonal rainfall patterns (Mamombe et al. 2016, Frischen et al. 2020). Zimbabwe's climate is predominantly subtropical characterised by high rainfall variability yet the economy is highly dependent on climate sensitive sectors making it more vulnerable to climate change (Unganai 1996). The adverse effects of climate change tend to slow down economic growth as resources are channelled towards addressing the negative impacts of climate change particularly food imports necessitated by poor yields. To this end, the country needs to better prepare to deal with the adverse effects of climate change through implementing adaptation measures meant to make communities and economic sectors more resilient to the associated impacts.

The vulnerability of different sectors to climate was accomplished through a process hereafter referred to as the Zimbabwe National Climate Vulnerability Assessment (ZNCVA). The ZNCVA is adopted in this study to understand the nature and extent of current and future threats of climate change to a given human or ecological system (IPCC 2007). This report is therefore an indicator-based assessment of past and projected climate change and its impacts on ecosystems and society. It also focuses on society's vulnerability to the impacts and sets the stage for the development of adaptation policies.

The ZNCVA was implemented by the Ministry of the Environment, Climate, Tourism and Hospitality Industry through a consultative process involving experts from high level, government officials drawn from various departments, representatives of developmental partners, policy planners, researchers, and program managers. It focussed on the vulnerability related to agriculture, livestock, fisheries, biodiversity and environment, health, water resources, natural disasters, transport, and infrastructure across the whole country. The assessment was based on different time periods e.g. current, medium term (2040) and long term (2080). The vulnerability was based on different emission scenarios based on Relative Concentration Pathways (RCP) of RCP 4.5 and RCP 8.5.

The ZNCVA provides the baseline for national adaptation and aims to provide the Government of Zimbabwe with a tool to assess the vulnerability of different sectors to climate change that will guide selection of suitable adaptation options. In order to access bilateral and multilateral funding, there is need for countries to identify priority adaptation options particularly with the commitments made at COP 21 guided by vulnerabilities across different sectors of the economy. Therefore the ZNCVA provide guidelines for adaptation planning and justification for project implementation in order to create a more objective decision making process through informing the development of national and transnational adaptation strategies and plans.

To this end the purpose of the ZNCVA is to make evidence-based decisions about program interventions to reduce vulnerability as follows:

- Identify vulnerability hotspots for further detailed analysis;
- Raise awareness of the drivers of vulnerability;
- Inform plans and decisions to reduce vulnerability; and
- Compare and prioritise vulnerable systems or locations.

1.2 Objectives

The main objective of the climate change vulnerability assessment was to apply climate scenarios to understand current and future vulnerability for selected sectors of the economy.

1.2.1 Specific Objectives

The main objective was achieved through the following set of specific objectives:

- understand past and present climate patterns at district level;
- define the climate impact on national priority sectors;
- determine the future pattern of climate vulnerability on different sectors of the economy based on future climate scenarios; and
- identify adaptation actions for the different sectors.

1.3 Climate Change Vulnerability in Zimbabwe

Historical climate observations indicate that there is high rainfall variability across the country and the frequency of extreme events particularly drought has been increasing since the 1980’s

(Mamombe et al. 2016, Frischen et al. 2020). In addition, the onset and cessation of the rainfall has changed significantly. As such, the country revised its agroecological regions (Manatsa et al., 2020) which necessitated the split of Region V into regions Va and Vb. This was necessitated by the observation that r some parts areas in the former region V are currently unable to sustain any type of rainfed agriculture due to the negative impacts of climate change. The increase in the frequency and intensity of extreme weather events has reduced the success of rainfed agriculture in most parts of the country. In addition, climate change is likely to result in the expansion in the range of disease vectors particularly those which are climate sensitive such as malaria, bilharzia and other tick-borne diseases.

Here the climate vulnerability assessment is used to systematically integrate and examine interactions between humans and their physical and social surroundings (Gizachew and Shimelis 2014). This makes it possible to express the complex interaction of climate change effects and the susceptibility of this system to its impacts. The IPCC framework is adopted to understand vulnerability as a function of the character, magnitude and rate of climate change and variation to which the system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). As such the system is vulnerable if it is exposed and sensitive to the effects of climate change and at the same time has only limited capacity to adapt. On the contrary, the system is less vulnerable if it is less exposed, less sensitive or has a high adaptive capacity. Exposure represents the background climate conditions and stimuli against which the system operates, and any changes in those conditions (Smit and Wandel 2006).

Within this perspective, vulnerability is understood to be the function of the system’s climate change exposure and sensitivity against its adaptive capacity that enables it to cope with related effects. This function can be expressed as follows:

Vulnerability =f(Exposure, Sensitivity)-Adaptive Capacity)

The components of vulnerability are disaggregated as depicted in figure 1. The potential climate change impacts are a result of the associated system’s exposure and sensitivity O’Brien et al (2007). On the other hand, the adaptive capacity is expressed by the interactions of structures and changes which are political and institutional as well as social and economic. The conditions such as institutional, biophysical, technological and socio-economic result in contextual vulnerability that determines adaptive capacity. The outcome vulnerability is a product of weighing adaptive capacity against the determined climate change potential impact. .

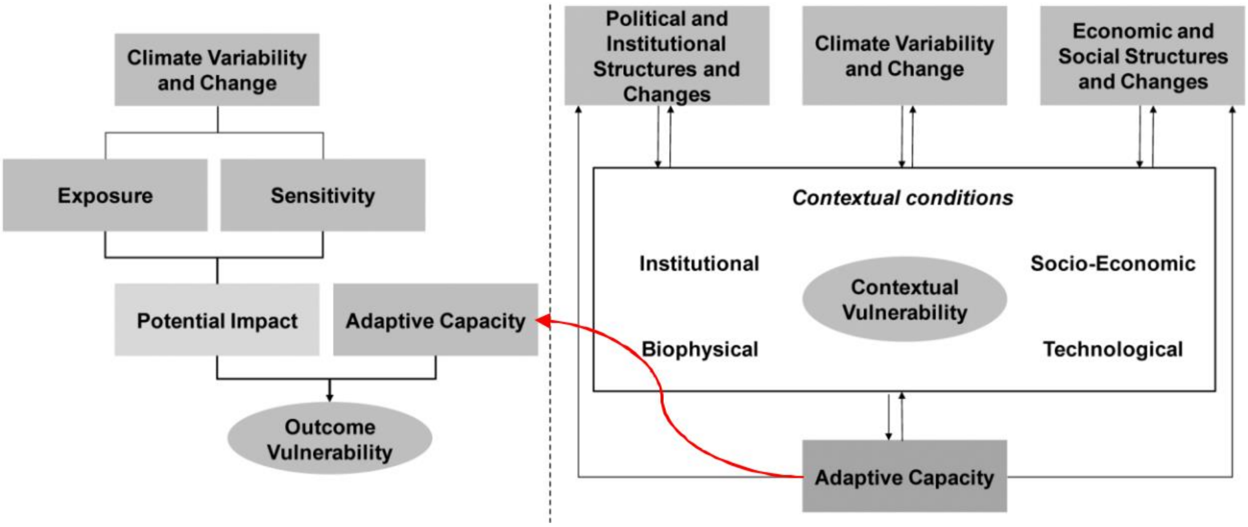


Figure 1: Vulnerability components used in this study *(Adapted from (O'Brien et al. 2007)*

Exposure is a combination of different climate induced natural hazards, while sensitivity represents the current and projected changes in the climate (precipitation and temperature). Adaptive capacity is the socioeconomic situation of the community, and how well they are able to deal with the potential impact (Exposure and Sensitivity). The resultant vulnerability based on the interaction of exposure, sensitivity and adaptive capacity and their related components are illustrated in figure 2a and 2b. It can be observed that the outcome vulnerability depends on the magnitude of the interactions where an increase in adaptive capacity results in the reduced sensitivity and exposure and vice *versa*. This demonstrates why enhancing adaptation is the preferred path to build climate change resilience whilst at the same time reducing exposure and sensitivity of the community.

(a) (b)

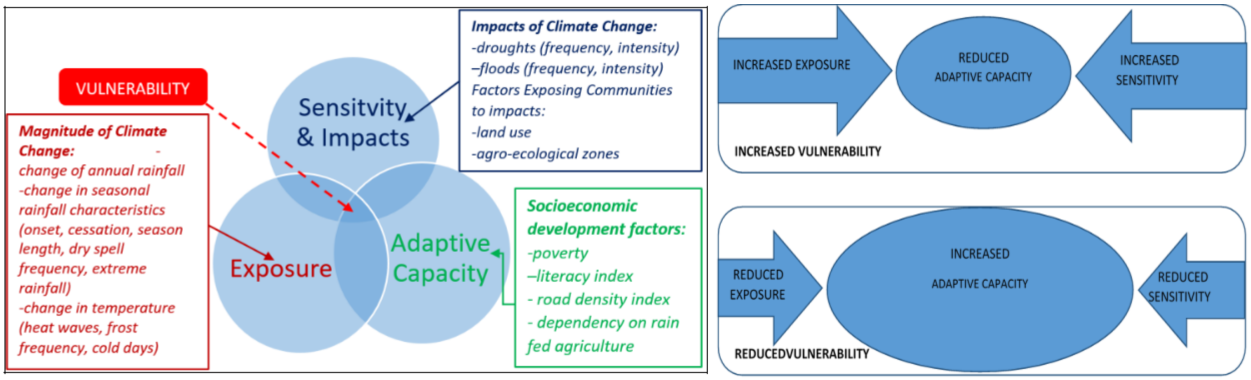
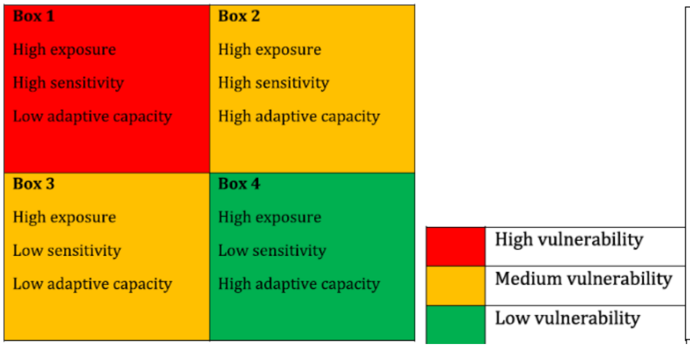


Figure 2: (a) Interaction of Exposure, Sensitivity and Adaptive Capacity components to determine vulnerability and (b) How modifications in Adaptive Capacity influence the resulting sensitivity and exposure magnitudes.

The scenario is better understood by focussing on figure 3. Depending on which 'box' the community/area being assessed falls in, vulnerability can be designated as high (Box 1), medium (Box 2, Box 3) or low (Box 4).



Box 1 High exposure High sensitivity Low adaptive capacity	**Box 2** High exposure High sensitivity High adaptive capacity
Box 3 High exposure Low sensitivity Low adaptive capacity	**Box 4** High exposure Low sensitivity High adaptive capacity

🟥	High vulnerability
🟨	Medium vulnerability
🟩	Low vulnerability

Note: If a community/area/sector has low exposure to climate change, it will most probably not be directly vulnerable to impacts of climate change. Its vulnerability will be indirect and through its link with sectors and systems in areas that are directly exposed to climate change. Although exposure is taken in the current, its precise nature and extent is determined through future scenarios.

Figure 3: Vulnerability scenarios

The inter-linkages among the different vulnerability components are illustrated in figure 4.

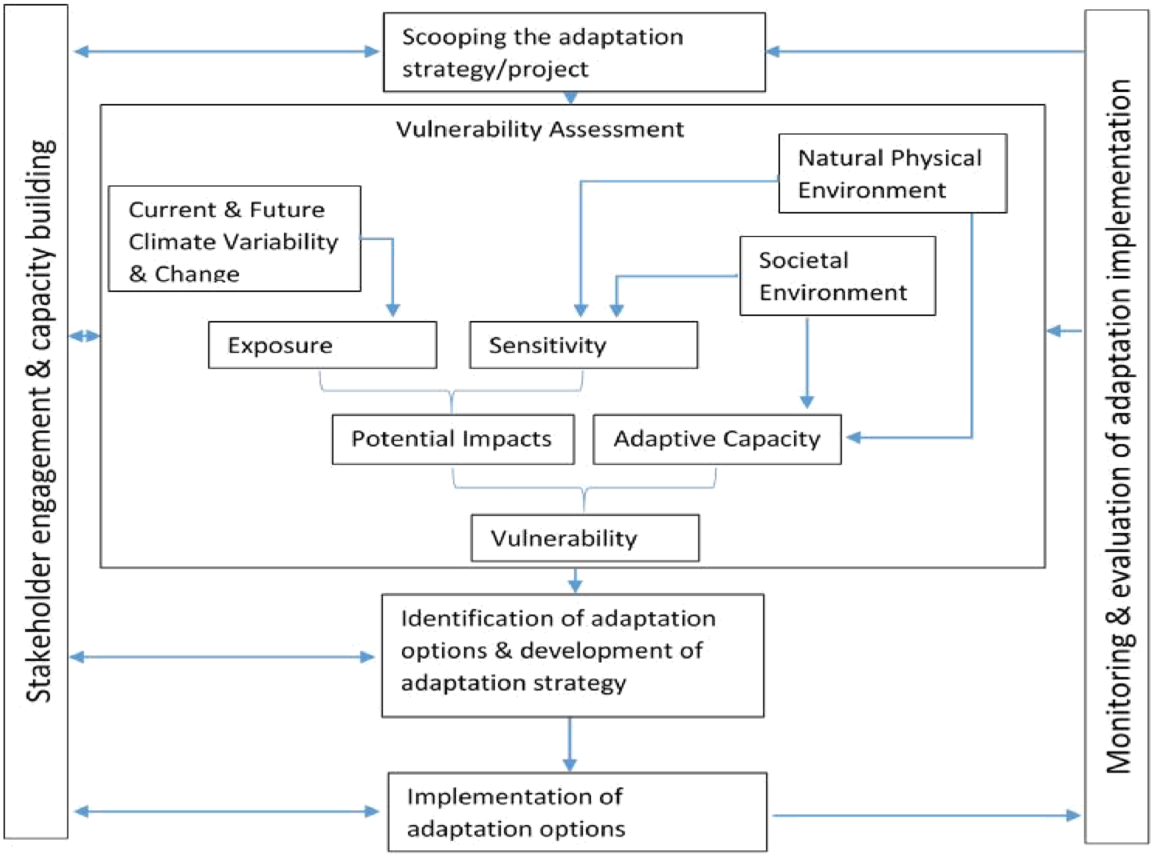


Figure 4: Vulnerability framework adopted in this study (*after Sharma and Ravindranath 2019)*

1.4 Scope of the vulnerability assessment

The vulnerability assessment was carried out for the following key sectors as informed by the Zimbabwe Climate Change Response Strategy (2014):

- Agriculture;
- Water;
- Energy;
- Wildlife & Biodiversity to include forest;
- Health;
- Tourism;
- Settlement & Infrastructure; and
- Gender & Vulnerable groups (cross cutting).

CHAPTER 2: MATERIALS AND METHODOLOGY/ TECHNICAL APPROACH

2.1 Introduction

The approach adopted in this study is based on the IPCC (2007) definition of vulnerability. The IPCC framework integrates physical and social vulnerability. The approach was complemented by the top-down and bottom-up vulnerability assessments. . The top-down approach starts from downscaled global climate projections. Conversely, the bottom-up approach is based on a participatory approach involving the population and stakeholders to identify climate-change stresses, impacts and adaptive strategies (Figure 5). Vulnerability outcome that focuses on the physical aspects follow a top-down approach, whereas contextual vulnerability concepts that concentrate on socio-economic vulnerability follow a bottom-up approach (Dessai et al. 2004).

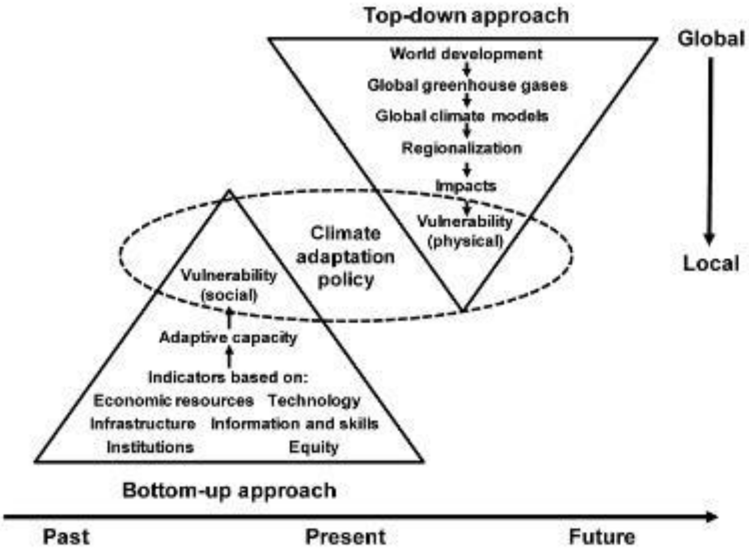


Figure 5: Illustration of bottom up and top down approach to inform climate change adaptation actions (*after Bhave et al., 2014)*

Although future impact of climate change on the biophysical environment is well understood, it is difficult to determine the future impact of climate change on society. This is because the indicators are often hard to predict and largely uncertain. Therefore in this study the assumption is that current levels of adaptive capacity and exposure will remain constant under the future climate change scenarios. Therefore focusing on RCP 4.5 and 8.5 future climate scenario impacts while the community's ability to respond (adaptive capacity) under current conditions will manifest itself as vulnerability.

2.2 Spatial Vulnerability Hotspot Mapping

The process of vulnerability hotspot mapping is essential in vulnerability assessment. The basis for the development of site specific adaptation options to reduce the risks associated with climate change is mapping of vulnerability across geographic regions (Gizachew and Shimelis 2014). Mapping of vulnerability indicators such as exposure, sensitivity, and adaptive capacity aids in communicating with policy makers and local stakeholders to support risk management and spatial planning (Eakin and Luers 2006, Lopez-Carr et al. 2014). There is need to map climate variability and extremes, including the sensitivity of populations and systems to these climatic stressors, and adaptive/coping capacities since all these components vary spatially (Daze et al. 2009, De Sherbinin et al. 2019). The results of vulnerability mapping are critical as they provide visual representation of the vulnerability of a particular region or sector to climate change. Mapping vulnerability is useful during multi-stakeholder discussion as this provides a basis for deliberations during adaptation planning (De Sherbinin et al. 2019) particularly in countries such as Zimbabwe where geographic information may not be easily accessible to all stakeholders.

Understanding the spatial pattern of vulnerability, its nature and characteristics is an essential step toward subsequent efforts to minimize the adverse impacts of climate change. This is because high vulnerability implies high risk whilst low vulnerability translates to low risk. However the magnitude of the risk depends on the magnitude of the hazard in question. It is essential to note that even if anthropogenic activities have a strong bearing on the characteristics of hazards, policy changes have a greater bearing towards the magnitude of vulnerability. To this end, mapping of climate change vulnerability hotspot maps is important for Zimbabwe as such maps indicate potential areas of high climate change vulnerability.. These maps are useful tools for policymakers as they indicate areas to be prioritized when investing in adaptation including indulging in additional efforts to minimise exposure and sensitivity.

The first step towards understanding vulnerability involves identification and quantification of indicators to be used as proxies.. These indicators are aggregated into vulnerability indices to facilitate the determination vulnerability across exposure, sensitivity and adaptive capacity. Eventually, these will spatial disaggregation of vulnerability to guide regional priorities for adaptation.

The process of hotspot mapping is a culmination of three steps. The key activities are summarized in Figure 6 and as follows:

1. Vulnerability assessments facilitate understanding of Zimbabwe's vulnerability to climate change;
2. Indicators and indices play the role of transferring vulnerability information into key vulnerability determinants that allows identification of hotspots; and
3. Hotspot mapping eventually aggregates the information generated in activities one and two into a map or series of maps.

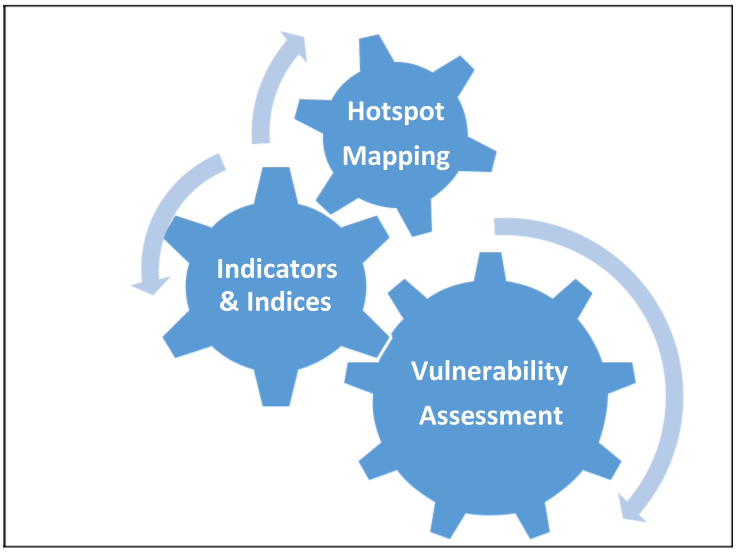


Figure 6: Main processes involved in current vulnerability hotspot mapping

The spatially disaggregated vulnerability across districts of Zimbabwe are presented as maps in this document.. The developed maps enable visualization of the spatial components involved, making information on climate risks more understandable and actionable for planners and administrators.

2.3 Stakeholders' involvement in the ZNCVA process

At local and national scales, vulnerability assessment should involve interaction with stakeholders. The involvement of local stakeholders and experts in the development of a national adaptation strategy bridges the gap between the top-down and bottom-up approaches to adaptation, thereby allowing national governments to make optimal policy decisions. Stakeholder involvement takes place at several stages of the assessment to determine the issues and responses to do with vulnerability to climate change. Participatory methods are applied in order to obtain first-hand documentation of vulnerability based on social conditions and physical stimuli from the perspectives of community members. Furthermore, when quantitative data are not available, expert opinions of regional stakeholders offer alternative sources of information. In addition, stakeholders can also provide valuable information on non-climatic stimuli that may be important for mitigating climate change impacts (Ziervogel and Downing 2004, Malone and Engle 2011).

2.4 Stakeholder Engagement

Climate change vulnerability assessment identified priority sector stakeholders for the country as informed by the Zimbabwe Climate Change Response Strategy (2014). Table 1 illustrates the stakeholders involved in the assessment.

Table 1: Stakeholders engaged during data collection

	Sector	*Stakeholders for data collection*
1.	Agriculture	Ministry of Lands, Agriculture, Water, Climate & Rural Resettlement. NGOs related to Agriculture
2.	Water	Ministry of Lands, Agriculture, Water, Climate & Rural Resettlement.
3.	Energy	Ministry of Energy & Power Development
4.	Wildlife & Biodiversity	Ministry of Environment Tourism & Hospitality Industry Environment Management Agency
5.	Health	Ministry of Health and Child Care
6.	Tourism	Ministry of Environment Tourism & Hospitality Industry
7.	Infrastructure Development	Local Government, Public Works & National Housing Ministry of Transport & Infrastructural Development
8.	Transport	Ministry of Transport & Infrastructural Development
9.	Gender & Vulnerable groups	Ministry of Women Affairs, Community Small & Medium Enterprise Development. Ministry of Public Service, Labour & Social Welfare Gender Related NGOs
10	Education	Ministry of Higher & Tertiary Education. Ministry of Primary & Secondary Education.

2.5 Vulnerability Indicators (VIs) used in this study

The vulnerability assessment adopted in this study follows the IPCC (2007) guidelines where indicators are exposure, sensitivity and adaptive capacity are considered.

2.5.1 Exposure Elements: Climate variability in Zimbabwe

Zimbabwe's rainfall is highly variable in both space and time with intensity, distribution, and frequency exhibiting a highly complex seasonal pattern (Manatsa et al. 2012, Mamombe et al.

2016, Manjowe et al. 2018). The rainfall and temperature pattern of the country is illustrated in figure 6. The peak rainfall is received from December to February, the period when the main rainfall bearing system, the Inter-tropical convergence zone (ITCZ) influences rainfall in the country (Manatsa et al., 2012, Manjowe et al. 2018). The annual rainfall varies significantly across the country with the high altitude areas in the east, central and north receiving higher rainfall while the low-lying areas are characterised by low rainfall. The low-lying areas make up the driest regions characterised by highly variable and unreliable rainfall. The eastern highlands of the country is characterised by orographic rainfall where the rainfall is least variable with annual amounts of over 1000 mm.

Both maximum and minimum temperatures generally follow maximum solar irradiance with high temperatures in summer and lower temperatures in winter. However the summer maximum temperatures are highest at the beginning of October (~ 31°C) to around 29°C, in December to February (Ngara et al. 1983, Manatsa et al., 2014). On the other hand minimum temperatures are lowest in June and July due to lack of clouds. Figure 7 shows the spatial distribution of rainfall in Zimbabwe. It can be observed that the southern, south-east and western regions are the driest which is aggravated by high evapotranspiration that reduces effective precipitation for crops. The eastern highlands which have the lowest temperatures and hence reduced evapotranspiration receives the highest amount of rainfall making it favourable for rainfed agriculture. Thus, the two major seasons and overall climate of Zimbabwe is primarily influenced and defined by precipitation and to a lesser extent by temperature.

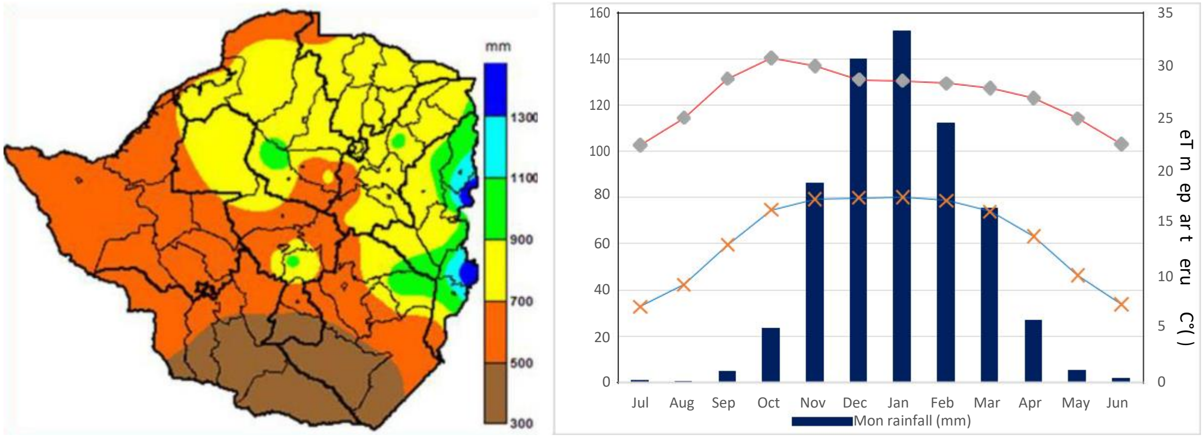


Figure 7: Spatial distribution for annual rainfall (left panel) and average monthly rainfall (right panel) for Zimbabwe for the period 1960-2019.

2.5.2 Changes in Rainfall Characteristics

Zimbabwe experiences relatively large inter-annual variability in rainfall compounded by climate change (Ngara et al. 1983, Manatsa et al., 2012). The different systems that influence the climate of the country especially those linked to ENSO phases result in varying amounts of rainfall across the country (Manatsa et al. 2012, Manjowe et al. 2018). They also impact on quality of the rainfall season through the varying onset and cessation dates, including the increase in the frequency and intensity of rainfall extremes. There has not been significant change in the rainfall amounts throughout the country though evidence points to a decreasing trend. However, significant changes in the intra-seasonal characteristics have been observed. These include the increase in the frequency and intensity of dry spells, reduced length of rainfall season, late onset and early cessation of the rainfall season and the reduction in the number of rainy days (Manatsa et al., 2020).

2.5.3 Changing seasonal characteristics of rainfall

The climate of Zimbabwe is characterised by a marked by a shift around 1981 that is statistically significant especially in mean temperature (Manatsa et al., 2020). Figure 8 shows that the country warmed on average by about 1 ° C while the rainfall shows a drying trend of about 35 mm.

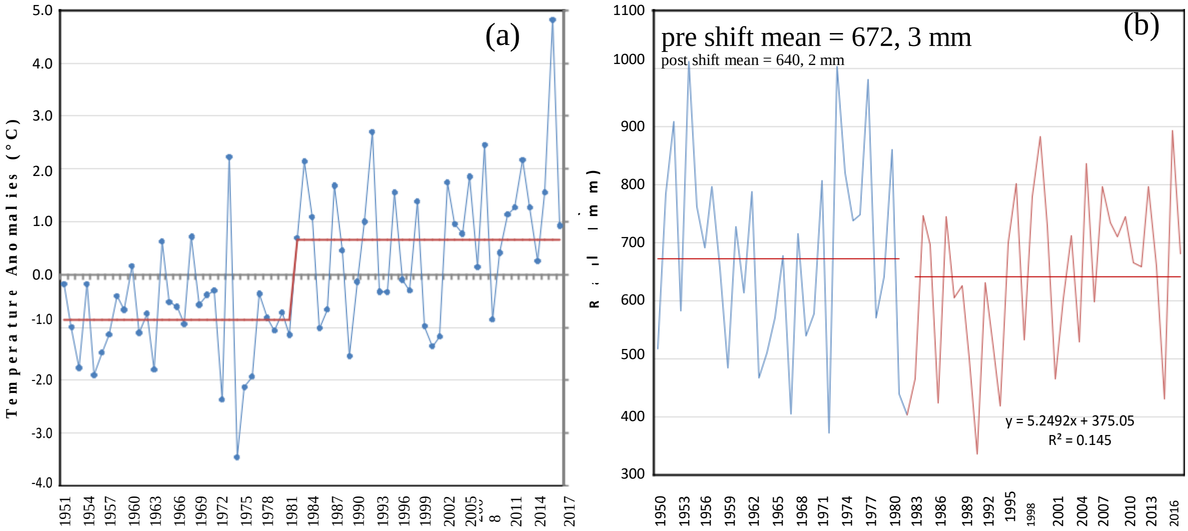
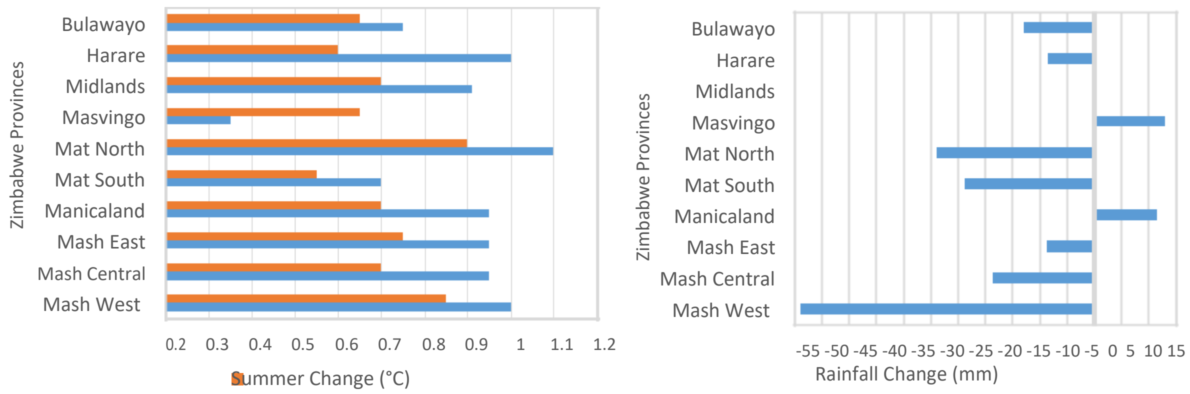


Figure 8: Significant shift in (a) temperature and (b) rainfall from 1950 to 2018 compared to the pre 1981 period (figures from Manatsa et al. 2020).

2.5.4 Rainfall and Temperature Changes relative to 1981 shift

Temperatures have increased for both winter and summer months in all the provinces though the changes have been more pronounced during winter. Summer warning of more than 1°C was experienced in Matabeleland North which had the highest increase of 1.1°C followed by Harare and Mashonaland West both with slightly more than 1°C. Although the summer increases did not exceed 1°C, Matabeleland North displayed the greatest warming of 0.9°C followed by Mashonaland West with 0.8°C. This means that Matabeleland North and Mashonaland West had the highest increase of winter and summer averaged temperatures. Winter temperatures increased rapidly than summer temperatures with Harare and Matabeleland North recording the highest percentage increase of about 7% to the pre-shift period (Figure 9a). Percentage increases in winter temperature was mostly 3% against summer increases which were mostly at least twice as much. It is only for Masvingo Province where the winter temperatures were higher during summer than winter with the province recording the least winter change of 0.4 °C.


(a)

(b)

Figure 9: Changes relative to 1981 for (a) summer and winter mean temperatures (°C) and (b) rainfall (mm)

The analysis for monthly summer rainfall across provinces is presented in figure 10. It is noted that on average, except for Masvingo and Manicaland that had marginal increases, the rest experienced reduction in amount of summer rainfall. The highest monthly average reduction relative to 1980 of more than 55 mm was observed in Mashonaland West followed by Matabeleland North with 29 mm where the percentage reduction amounted to 34% and 21% respectively (figure 10). The results our analysis demonstrates that Mashonaland West is the worst affected province in terms of temperature and rainfall changes. Rising temperatures and reduction in rainfall affect agricultural output and other economic sectors negatively impacting livelihoods in the area.

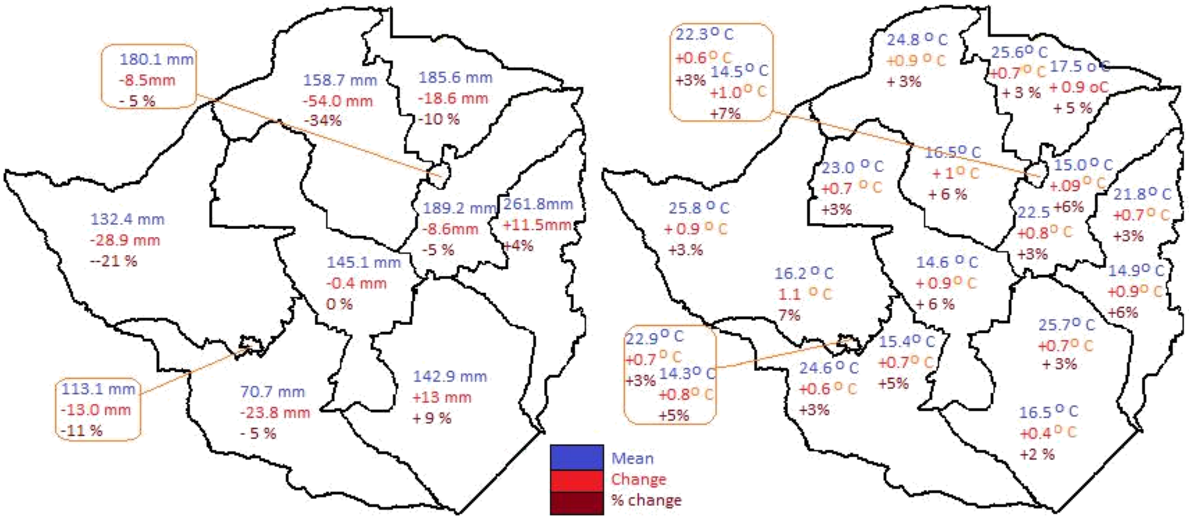


Figure 10: Monthly rainfall average from November to March (left panel) and, peak summer (Oct to Nov) and winter (Jun to Jul) temperatures (left panel)

The top value is the average for the province and the middle is the change relative to the 1981 shift while the bottom value is the corresponding percentage change

In addition to shift in rainfall and temperature, most parts of the country experienced shift in intraseasonal characteristics of rainfall. However, the greater part of the country now experiences a late start to the season by as much as 18 days while some regions experience an early start to the season (figure 11). It can be noted that regions such as Mashonaland Central, Mashonaland East, Mashonaland West, Matabeleland North, northern parts of Midlands and the greater part of Manicaland, now typically experience a late start to the rainfall season while Matabeleland South, Masvingo and southern parts of Matabeleland North shifted towards an early start.

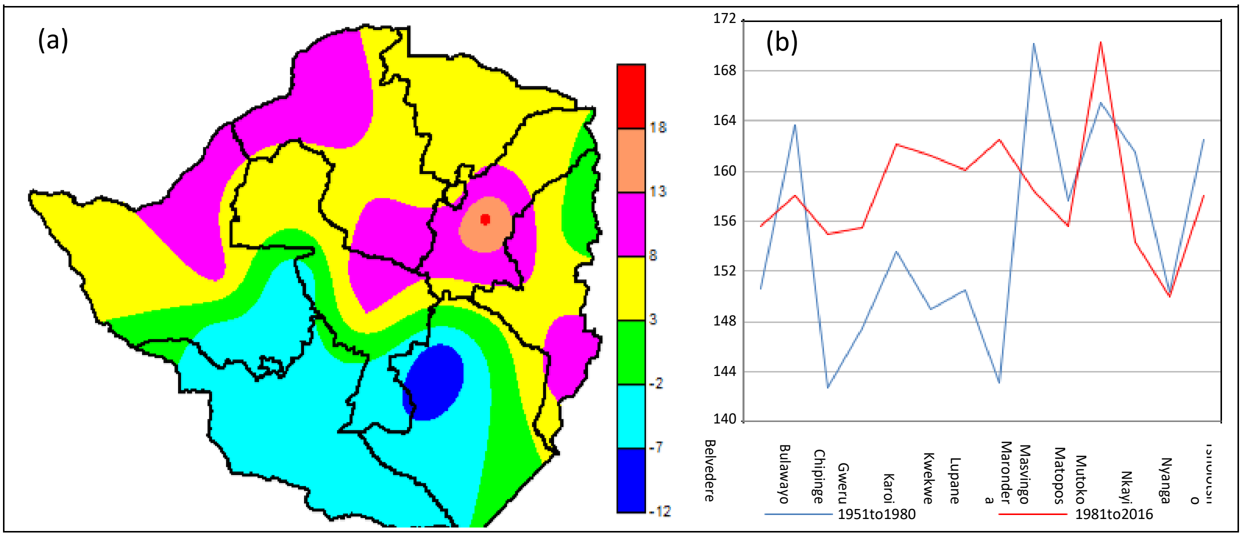


Figure 11: Changes in the start of the rainfall (mm) season between the period 1951 to 1981 and from 1982 to 2016 for (a) Zimbabwe and (b) selected towns. (*Rainy days are in Julien days*)

Figure 12 shows that the larger part of the country experienced a reduction in the length of the rainfall season of up to 30 days that is accompanied by a decrease in the number of rainy days. On the other hand, the eastern highlands (around Nyanga) has had the length of the season increased by up to 15 days and an increase in the number of rainy days of between 1 to 14 days thereby positively impacting on agricultural activities.

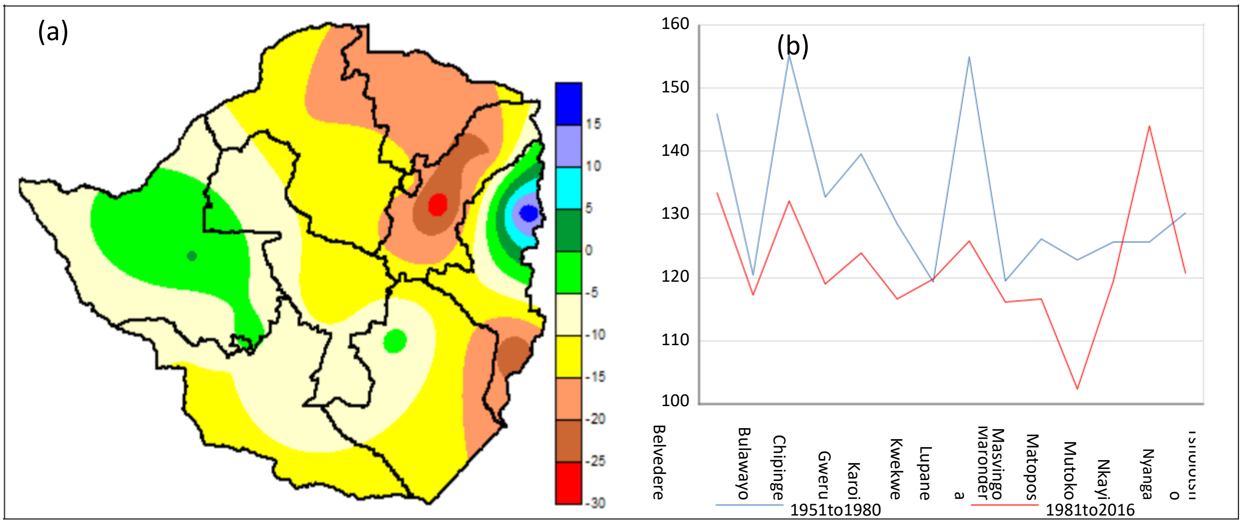


Figure 12: Spatial variation in the changes in the length of the rainfall season between the period 1951 to 1981 and from 1982 to 2016 for (a) Zimbabwe and (b) selected towns. (*Negative values indicate contracting whilst positive values imply expansion of the rainfall season*)

The contraction of the season and reduction in the number of rainy days should be suppressing the water availability during the growing season thereby negatively affecting the types of crops and livestock that thrive in the respective areas. This is further aggravated by the observation that most of the country is now experiencing an increase in the number of dry spells during the rainfall season of up to 20 days (Figure 13 and 14).

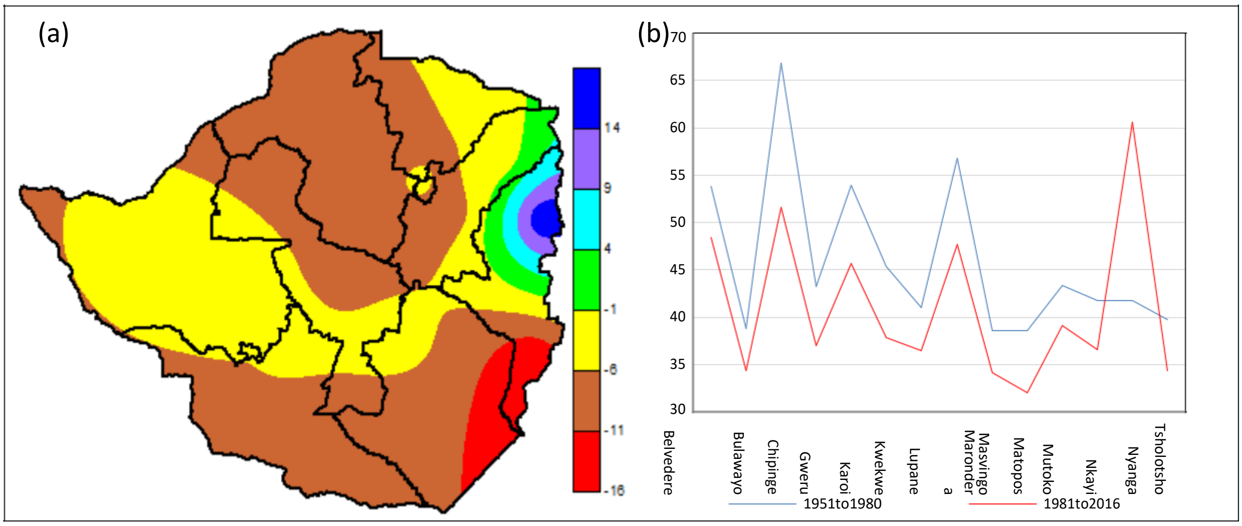


Figure 13: Spatial variation in the changes in the number of rain days between the period 1951 to 1981 and from 1982 to 2016 (a) Zimbabwe and (b) selected towns. (*Negative and positive values indicate the number of rain days below and above the average respectively*)

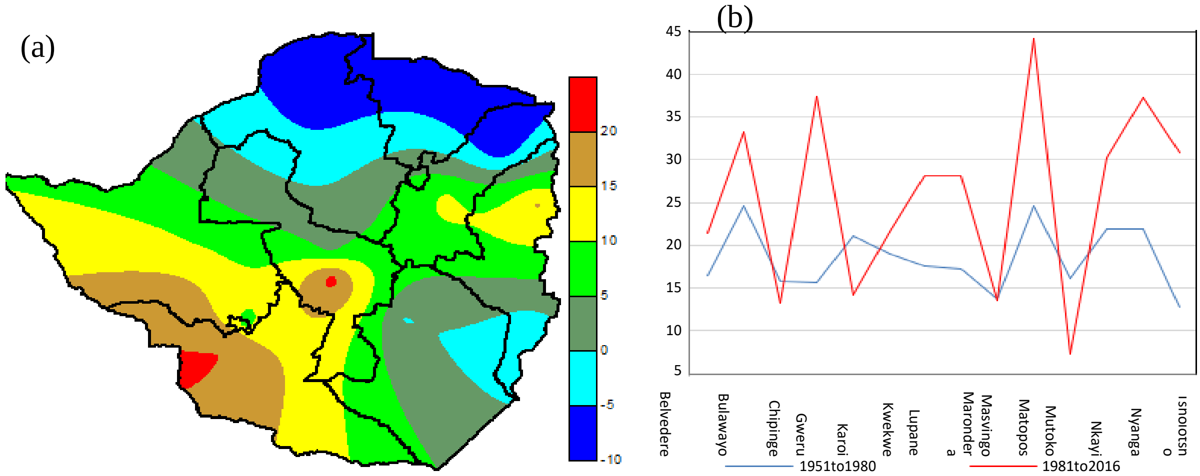


Figure 14: Spatial variations in changes in the length of longest dry spells between the period 1951 to 1981 and from 1982 to 2016 for (a) Zimbabwe and (b) selected towns. (*Negative and positive values indicate the length of dry spell days below and above the average length respectively*)

We observe that Zimbabwe's climate started to change from the 1980s evidenced by the altered magnitude and frequency of extreme climate events. In addition there have been changes in the frequency of cold days, cold nights, and frost have decreased drastically. On the other hand, the frequency of hot days, hot nights, and heat waves, has significantly increased. Temperature rise has been observed across all seasons, but particularly during the dry season from April to October. Variations exist between locations, with higher warming rates observed in lower altitudes along the main river valleys of Zambezi, Save and Limpopo. Rainfall patterns have also changed especially the intra-seasonal characteristics. On the overall annual rainfall changes remain insignificant but with a decreasing trend. It is the summer rains which are declining continuously with droughts becoming longer, more intense, and tending to continue across rainy seasons. The frequency of droughts and heavy rainfall that results in floods has also significantly increased in the in the last 30 years.

2.6 Changes in the Agroecological boundaries

The changes in climate for Zimbabwe is characterised by increase in temperature and erratic rainfall patterns. The country is divided into five agro-ecological regions based on a combination of factors including rainfall regime, temperature and the quantity and variability of average rainfall, as well as soil quality and vegetation. The suitability of cropping declines from Natural Region (NR) I through to NR V. The shift in both rainfall and temperature detected in 1982 resulted in a shift in these agro-ecological regions.

The characteristics of seasons such as changes in inter-seasonal rainfall and temperature, onset, cessation, length of the growing season and dry spells and evapotranspiration have undergone significant changes. The changes in agroecological regions had a significant effect on the vulnerability assessment since it directly affects rainfall patterns and crop and livestock production (Figure 15). Notable changes include the contraction of NR II, NR III and NR IV as well as expansion of NR V (Manatsa et al., 2020). Of significance in the new regions is the further division of NR V into NR Va and NR Vb where the latter can no longer economically sustain any form of rainfed agriculture, even the previously recommended traditional grains. However, on the overall, the diverse agro-ecologic zones in the country demonstrate different levels of sensitivity to climate change impacts.

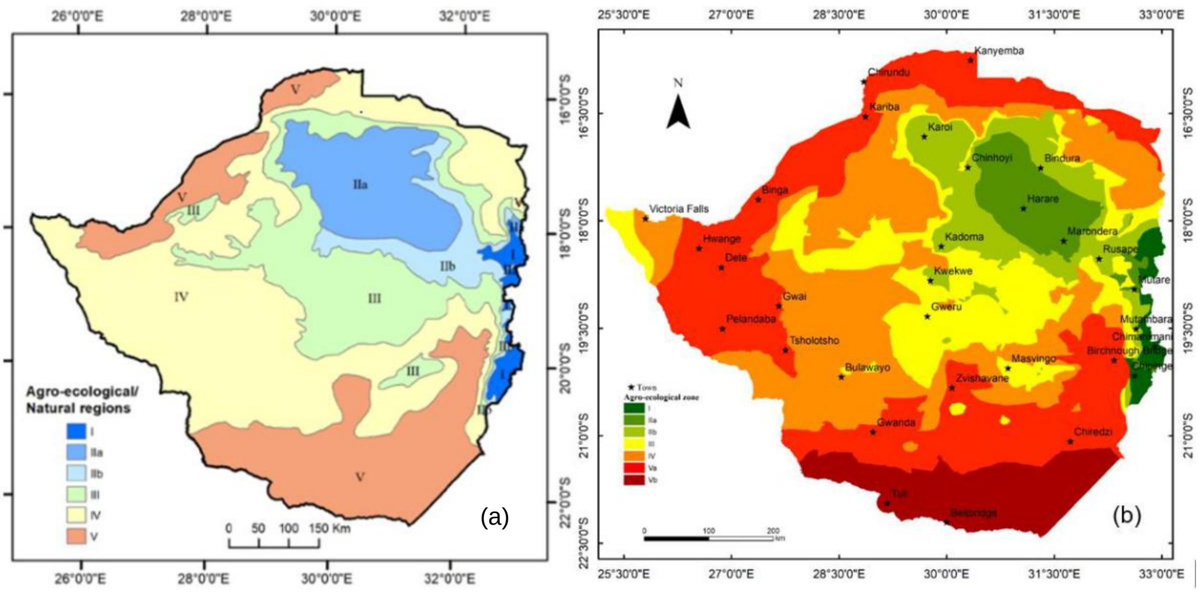


Figure 15: Agro-ecological regions of Zimbabwe (a) in current use (from Vincent and Thomas, 1962) and (b) the revised map (from Manatsa et al. 2020) to depict the relive differences in the spatial changes of the natural regions when (b) is compared to (a)

2.7 Drought hazard

The agriculture sector is one of the key drivers of Zimbabwe’s agro-based economy, contributing 17% to the country’s GDP (Tomlow et al. 2006). Agriculture is mostly rainfed whilst a small percentage depends on irrigation, where only 4.3% of cultivated land is irrigated at national level. The predominance of rainfed agriculture and a lack of efficient water infrastructure significantly contribute to food insecurity and low household incomes. As such, the most important agricultural risk in Zimbabwe is drought as it affects agricultural production and threatens food security (Tomlow et al. 2006, Frischen et al. 2020). Therefore the vulnerability of the agricultural system was determined mostly by analysing the drought hazard on both irrigated and non-irrigated crops (Frischen et al. 2020).

Analysis of meteorological drought using the drought intensity in the past three decades reveal increased frequency of intense drought across the country in the following years; 1991/92, 1994/95, 2002/03, 2015/16, and 2018/19 (Frischen et al. 2020). The most affected areas include Matabeleland North, Matebeleland South and some parts of Masvingo. However in some years of mild droughts (e.g., 2003/04, 2006/07, 2011/12, and 2017/18), the distribution was not uniform but characterised by isolated patterns with Mashonaland East and Manicaland being generally less affected by drought.

The occurrence of droughts results in reduced crop, rangeland, and forest productivity, increased fire hazard, reduced dam levels resulting in lowering of water tables and drying of most wells, increased livestock and wildlife mortality rates, and damage to wildlife and loss of fish habitat. The impacts also inflict huge losses in the related agro-production industry chain. Drought induced economic impacts occur in agriculture and related sectors because of the reliance of these sectors on surface and groundwater. Drought is also associated with insect infestations, plant disease, and wind erosion. The incidence of forest and range fires increases substantially during extended periods of droughts, which in turn places both human and wildlife populations at higher levels of risk.

On the environment, the drought impacts mostly manifest as a result of damages to plant and animal species, wildlife habitat, and air and water quality, forest and range fires, degradation of landscape quality, loss of biodiversity, and soil erosion. Some of these effects are short-term, whereby many species eventually recover from this temporary aberration when conditions rebound to normal after the drought. However, increased frequency and intensity that are occurring in the recent decades tend to last for some time to the extent of even becoming irreversible. Of note is the current disappearance of wildlife habitat in most provinces of the country where the degradation manifests through the loss of wetlands, lakes, and vegetation. In this case, the degradation of landscape quality necessitated by increased soil erosion and gully formation is leading to a more permanent loss of biological productivity.

Lack of moisture during drought and the accompanying increased insect infestations, pests and disease causes plants and trees to wither and die thereby increasing fuel for wildfires. The more intense the drought the more the fuel generated and the more frequent the droughts the more intense wildfires and the more the wildfires respectively. This adversely affects the economy, the environment, and society such as destroying neighbourhoods, crops, and habitats. On the social front, drought leads to fewer recreational activities and reduced tourist activities. Increased malnutrition is not uncommon during local droughts due to the resulting crop failure which also is associated with high mortality rate among children.

2.8 Flood Hazard

Floods impact the country’s economy and the well-being of Zimbabweans. They are seasonal and more localised and mostly affect low lying areas. The flood prone areas were designated by ZINWA as Muzarabani, Gokwe, Middle Sabi, Tsholotsho and Chikwalakwala. The floods in these regions are mainly a result of backflow, resulting from smaller tributaries failing to empty their water in flooded major rivers. Other floods occur downstream after a dam wall failure or there has been a deliberate act to open the flood gates of an overflowing dam. Otherwise in general, flooding normally occurs across the entire country in years with above-normal rainfall, as well as those events with heavy rainfall storms. For example in 2018 the country received the highest amount of rainfall which has never been experienced since 1950 record.. Some of the flooding is associated with cyclones for example cyclone Eline in 2000/2001, Dineo in 2017, Japhet in 2018, Idai in 2019, Chalane in 2020 and Eloise in 2021.

These cyclone induced floods mostly affects the southern parts of the country which are low-lying.

The immediate impacts of flooding include loss of human life and damage to property. Communication links and vital infrastructure such as power plants, roads and bridges are damaged leading to disruption in economic activities and prevent access to essential public services. Damage to infrastructure also causes long-term impacts, such as disruptions to clean water, wastewater, electricity, sewerage, telecommunications and electricity, transport, communication, education and cut access to health care.

A secondary impact of floods can be the contamination of floodwaters with chemicals and sewage. This can pose a threat to the health of people and animals and can increase the risk of exposure to waterborne diseases. In the agricultural sector, which is the mainstay of rural livelihoods, destruction of crops is effected through washing away of fields, water logging and leaching which can ruin crops, delay harvests, spoil produce, remove or contaminate valuable topsoil and cause death of livestock. This can lead to food shortages and higher costs of farm produce. On the other hand flooding can have social impacts on a community causing sporting events to be cancelled and even reduce tourist arrivals.

2.9 Sensitivity Elements

2.9.1 Socio-demographic and economic conditions

Zimbabwe’s population is growing at the rate of 1.1% per annum based on the 2012 projection and is expected to double by 2050. This implies a potential increase in demand for food and water and land claims resulting from higher demand. There is already a visible increased trend of migration from rural areas towards the main cities which is resulting in the urban sprawl and mushrooming of illegal settlements.

Table 2: National Climate Risks, sources of vulnerability and related climate change impacts

Key Sources of Vulnerability		
• Higher confidence in rising temperatures • Uncertain changes in rainfall patterns • Increase in rainfall extreme events in both intensity and frequency of droughts and floods • Shortening of growing season • Increase in landslides		• Environmental degradation • Loss of forest cover • Increase in water scarcity • High risk to rain-fed agriculture • Threats to winter cropping due to higher temperatures

Key Sources of Vulnerability		
• Higher confidence in rising temperatures • Uncertain changes in rainfall patterns • Increase in rainfall extreme events in both intensity and frequency of droughts and floods • Shortening of growing season • Increase in landslides		• Environmental degradation • Loss of forest cover • Increase in water scarcity • High risk to rain-fed agriculture • Threats to winter cropping due to higher temperatures
Identified Climate Change Impacts		
• Declining agricultural productivity • Food insecurity • Land & ecosystem degradation • Shifts in intra-seasonal rainfall characteristics • Increase in climate related disasters • Water scarcity • Food & nutrition insecurity		• Negative health impacts for humans & livestock • Intensified Landslides & erosion • Increase in human-wildlife conflict • Deterioration in biodiversity • Increase in settlement & infrastructure damage

2.10 Adaptive Capacity Indicators

The adaptive capacity indicators were selected after an extensive review of literature and reports. These were provided by the most recent data from public sources including the Zimbabwe National Statistics Agency (ZIMSTAT), the Zimbabwe Vulnerability Assessment Committee (ZimVAC) and the Poverty, Income, Consumption, and Expenditure Survey (PICES) reports (Annex 1). These data are reliable and comparable over time because they are collected annually by government specialized agencies.

Stakeholders who participated in selection of vulnerability indicators were drawn from the eight provinces of Zimbabwe. These included people from the meteorological services, social welfare and agriculture. These teams carefully selected variables which were applicable to the Zimbabwean context by taking into account the impact of such variables and the availability of quantitative public sources data at district level. 23 variables were selected (Annex 1). However to objectively extract the dominant vulnerability indicators from these 23 variables, principal component analysis (PCA) was applied.

A scree-plot was then used to truncate these variables resulting in the selection of only four factors which explained a cumulative variance of about 74% of the total variance (Table 3). These are poverty (~54.5%), dependency on rainfed agriculture (~8.1%), household head characteristics (~6.3%) and prevalence of chronic conditions (diseases) among households (~5.0%). These four factors shown in Table 3 were the ones selected to approximate the district vulnerability. It should be noted that the inclusion of strong indicators according to literature such as institutional strengths, overall per capita income, household tap water connection, school-dropout rates, groundwater availability and quality, and percentage of the population dependent on natural resources for livelihood would have changed the vulnerability of the districts, had the data have been available.

Table 3: Significant vulnerability indicators

Component	Initial Eigenvalues		
	Total	**% of Variance**	**Cumulative %**
1. Poverty	11.999	54.542	54.542
2. Dependency on rainfed agriculture	1.776	8.072	62.614
3. Household head characteristics	1.383	6.285	68.899
4. Chronic diseases among household	1.099	4.996	73.895

Stakeholders agreed with the outcome of the principal component analysis in the selection of the dominant factors which define the vulnerability of a community. They also agreed with the given rationale for the selection. However, they also suggested for inclusion other indicators which had not scored significant values in the principal component analysis. These are shown with asterisks in the Table 4 together with the stakeholder rational for inclusion. After realising that they are strong correlated to the already selected variables, it was decided to discard them. Again, it has to be noted that their inclusion could have also have changed the outcome of the ultimate vulnerability indices for the provinces that are presented in this work.

Table 4: Vulnerability indicators, their relationship with vulnerability

Indicator	Construction (Yr of data in brackets)	Dimension	Category(relevant sectors in brackets)	Rationale for selection
Population living below the poverty datum line	Percentage of population living below the poverty line.	Sensitivity (Positive)	Socio-economic features & livelihood (General)	People with extremely low incomes, are among the most vulnerable: they have little to no financial capital; so, they have the least capacity to adapt to impacts of climate risks (O'Brien, et. al., 2008)
Proportion of households dependent on rainfed agriculture	Number of households dependent of rainfed agriculture per 1000 households	Sensitivity (Positive)	Biophysical (Agriculture)	Rainfed agriculture is highly sensitive to the vagaries of weather. Lack of irrigation indicates a lack of adaptive capacity to mitigate the impacts of climate risks, leading to increased crop loss and reduced income of households dependent on rainfed agriculture
Proportion of child/female headed households	Number of children/ female headed households	Adaptive Capacity (Negative)	Socio-economic Features & livelihood (General)	Women headed households are disadvantaged because they experience the burdens of poverty, gender discrimination & absence of support as heads of households. In addition, children headed households at times do not qualify for support due to age and most are not aware of their rights and hence are vulnerable to most social ills such as abuse from adults.

Indicator	Construction (Yr of data in brackets)	Dimension	Category(relevant sectors in brackets)	Rationale for selection
				They are at times taken advantage of by the community. Adaptive capacity of these vulnerable groups severelydeduces adaptive capacity
Chronic diseases among households	Number of households with at least a member with chronic disease(s)	Sensitivity (Positive)	Biophysical (health)	Lack of proper drainage, high incidence of open defecation, & frequent occurrence of floods lead to an increase in exposure to waterborne pathogens. Temperature and rainfall variations can foster higher vector borne disease occurrence. This can lead to chronic waterborne & vector borne diseases.
Available forest area available for the community**	Area of total forest in km^2 per 1,000 rural population (2019)	Adaptive Capacity (Negative	Biophysical (Forests)	Forests are an important source of alternative livelihood & food through the extraction of non-timber forest products (NTFPs). Forests also provide essential ecosystem services for the sustainable productivity of rural economies & building of adaptive capacity
Road network density**	The total length of surface road in km/Total geographical area in sq. km. State of the road was also taken into consideration to reduce the index values (2019)	Adaptive Capacity (Negative	Institution and infrastructure (General)	Under extreme weather events, the role of transport becomes crucial. This indicator focused on accessibility and connectivity, which are essential in regions that are exposed to climate & disaster risks, to allow for relocation and provide support services. It also gave some idea of the overall development of a region, because with better connectivity comes better access to markets, essential services, a potential for industrialisation, etc.

*Indicators with ** did not come out as major factors of vulnerability in the PCA though the stakeholders emphasized on their dominance*

2.11: Deriving Vulnerability Index

The exposure elements are represented by frequency of occurrence of droughts and floods. The sensitivity index was determined using district income, and poverty indices whilst the adaptive capacity was derived from literacy rate and infrastructural assets particularly accessibility to water. These were determined by stakeholders during the various workshops which were conducted throughout the country. To select the significant vulnerability indicators within the provinces, the selected indicators shown in figure 3 were analysed using an integrated vulnerability assessment approach. The first step was to normalise or standardise the indicators since they had different units and scales. All indicators were converted to range between 0 and 1 and they become unit less after considering the functional relationship with vulnerability. The weighted sum of indicators under each of exposure, sensitivity and adaptive capacity were used to derive the aggregate vulnerability index for each district and mapped spatially in a GIS.

2.12 Climate Change in Zimbabwe

Climate change is a long-term process, but the extent to which individual weather events are influenced by climate change can increasingly be estimated by global climate models (IPCC 2013). Hence the pattern of climate in any given region can be guided by freely available global climate models that help decision makers to understand future climate projections (Dosio 2017). In this project, the Coupled Model Intercomparison Project Phase 5 (CMIP5) framework which develops climate models used by the Intergovernmental Panel on Climate Change (IPCC)'s for its assessment reports was applied (Taylor et al. 2012, Gutowski Jr et al. 2016). For the purposes of the current NAP reporting, high resolution future climate simulations were applied to understand future climate projections. The future climate was derived from an ensemble consisting of 7 RCMs downscaled under the Coordinated Downscaling Experiment (CORDEX-Africa domain) driven by 10 GCMs (Weber et al. 2018). The projected changes were done for two Representative Concentration Pathways (RCPs) which are RCP 4.5 and RCP 8.5. The former represent slower emission reductions that stabilise the CO_2 concentration at about 540 ppm by 2100 whilst the latter assumes increases in emissions leading to a CO_2 concentration of about 940 ppm by 2100. Both intraseasonal and interannual variability was analysed in as much as their future tendencies would impact on the national priority sectors that include Agriculture, Water, Energy, Wildlife & Biodiversity to include forest, Health and Tourism

Rising annual temperatures display a fast rising trend in all seasons that is more rapid than the global average. This concurs with the IPCC Fifth Assessment Report, which indicated that during this century, temperatures in the African continent would rise more quickly than in other land areas particularly in more arid regions (Weber et al. 2018). Climate change is not only increasing ambient temperature but also accelerating the frequency, duration and intensity of extreme weather and climate events such as heavy precipitation and droughts, and causing significant impacts to the mentioned national priority sectors. Climate change-related reductions in land productivity and habitability and in food and water security can also interact with demographic, economic and social factors to worsen regional exposure to the changed climatic elements. According to the IPCC, it is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent (Parry et al. 2007). It is likely that future tropical cyclones will become more frequent and intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures (Parry et al. 2007).

2.13 Future Rainfall Projections

The future projections indicate a tendency for rainfall to decrease under both RCP 4.5 and 8.5 (figure 16). The mean rainfall decreases by about 150mm under RCP 4.5 but with a further decrease of 200mm for RCP 8.5. Monthly rainfall analyses of these decreases show that they are more pronounced in the rainfall season especially from October to March which is a critical period groundwater recharge and agricultural production.

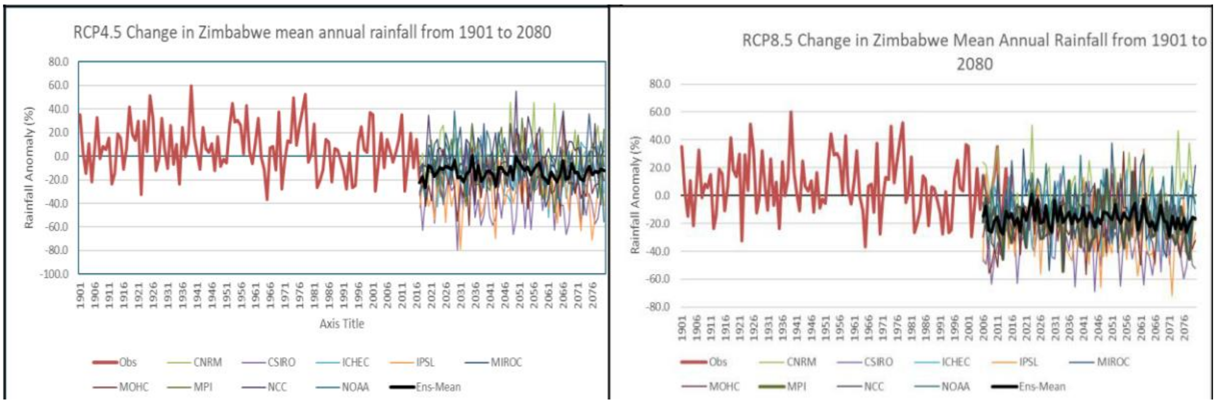


Figure 16: Temporal manifestation of Zimbabwe annual rainfall for RCP 4.5 (left panel) and RCP 8.5 (right panel)

The spatial distribution of the annual precipitation for the RCP 4.5 relative to the near term (second panel), medium term (third panel) and long term (fourth panel) relative to the baseline is illustrated in figure 17. It can be observed that for the near term the highest reduction of about 10% is occurs in the southern parts of Matabeleland South Province and southwest of Masvingo as well as in the eastern Highlands. The Zambezi valley seems to have a marginal increase in rainfall of up to 4% and is the only increase for the period. The scenario intensifies considerably for the long term where the pattern in the near term is retained but with the decreases spreading within the three provinces of Matabeleland South, Masvingo and Manicaland. However marginal increases of up to 4% are restricted to the Zambezi Valley portion of Mashonaland West province. Hence the general trend displays marginal percentage increase over the Zambezi valley but decreasing south eastwards to attain the highest percentage decrease over the south and eastern parts of the country.

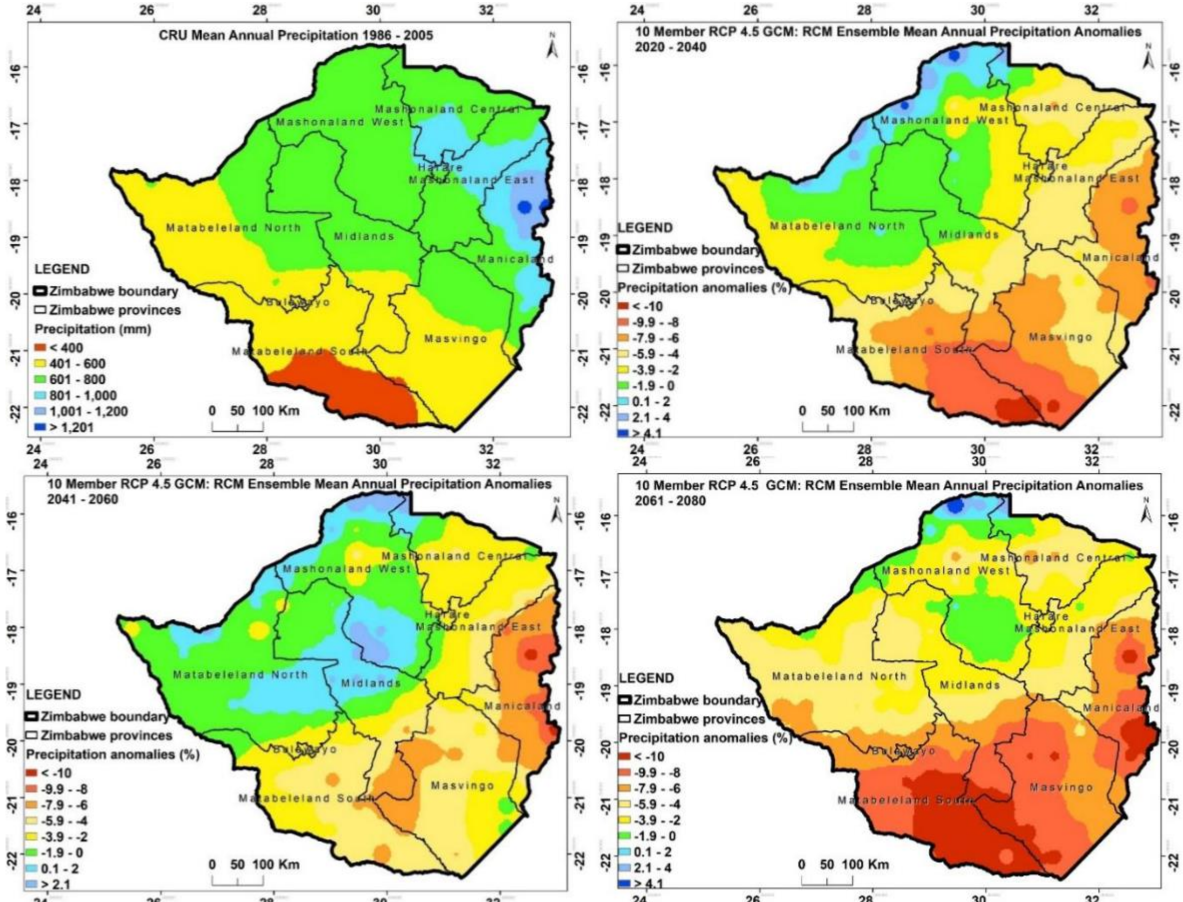


Figure 17: Spatial distribution of rainfall based on current climate (1986-2005) (1st panel), and projected rainfall anomalies for 2020-2040 (2nd panel), 2041-2060 (3rd panel) and 2061-2080 (4th panel) based on RCP 4.5

As for the RCP 8.5, the pattern is slightly different where the near term shows marginal increases of up to 10% in areas to the north of the central watershed with decreases to its south which intensifies to up to 10% over Beitbridge (Figure 18). The midterm depicts general intensification south of the central watershed with the worst decreases of more than 10% over Matabeleland South, Chiredzi and Manicaland. It is important to note that although the decreases are for annual totals, the greatest contribution is during the rainfall season from November to March.

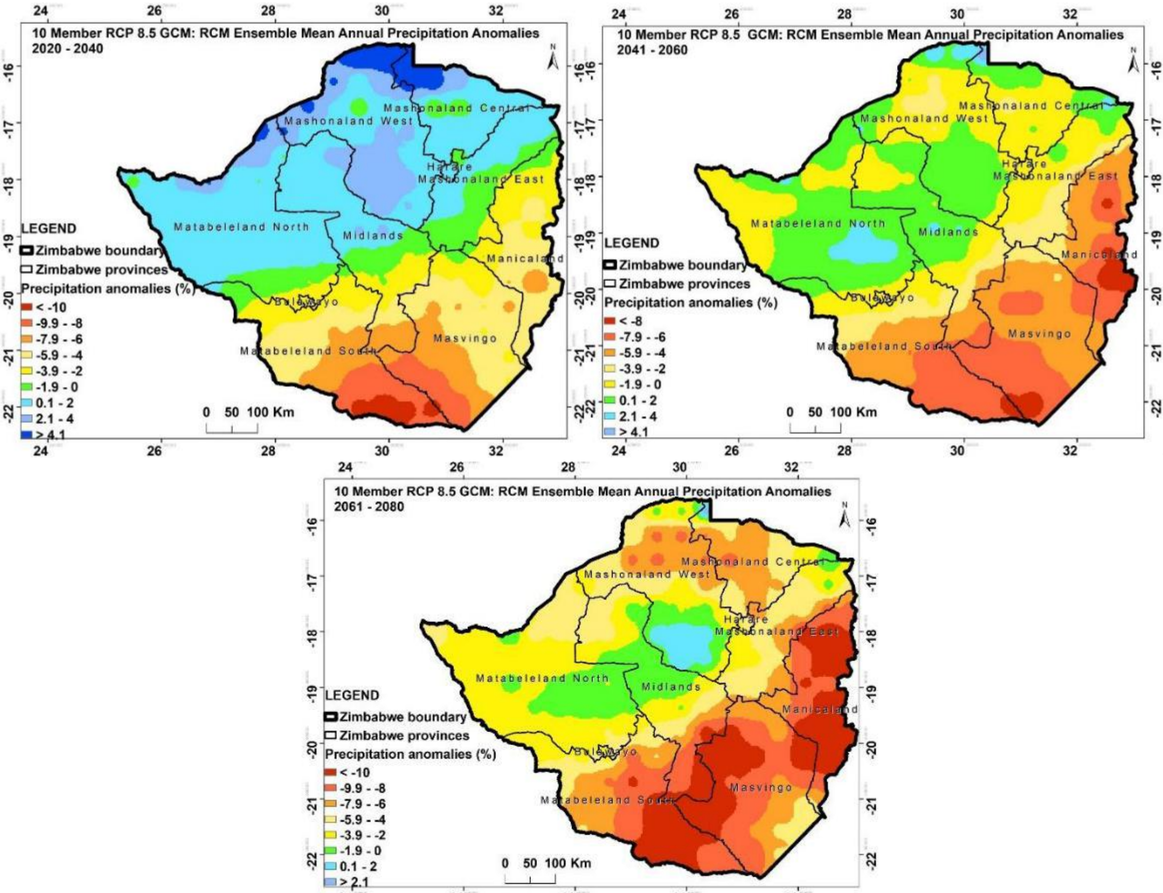


Figure 18: Spatial distribution for Zimbabwe mean annual CRU rainfall for the periods 2020-2040 (1st panel), 2041-2060 (2nd panel) and 2061-2080 (3rd panel) for RCP 4.5

2.14 Changes in rainfall extreme events

In order to capture the intra seasonal changes in the rainfall extremes the 10-year return period rainfall episodes were analysed, obtained for the 5-day cumulative rainfall, which is usually considered a good measure of these extremes. Figure 19 illustrates that for the middle term, the cumulative rainfall amount increases from 200 mm to above 250 mm for RCP 4.5 and 220 mm for RCP 8.5. This observation is consistent with many places around the world where the cumulative rainfall sum in 5 days in a 10-year period is projected to increase. This is because a warmer atmosphere contains more water vapour and increases the intensity of the whole hydrological cycle, with precipitation patterns that are likely to change homogenously in time and space. As such the future climate raises the likelihood for strong rainfall events and particularly towards extremes. This will most likely lead to flooding. Therefore when the changes in annual rainfall amounts is taken into consideration, the country's rainfall will not only be reduced but there will also be an increase in its intensity. As a result, most of the human activities can be largely affected. For example, the transportation lines for fuel can be interrupted by local flood, or distribution networks can be disturbed by excessive rainfall and flooding.

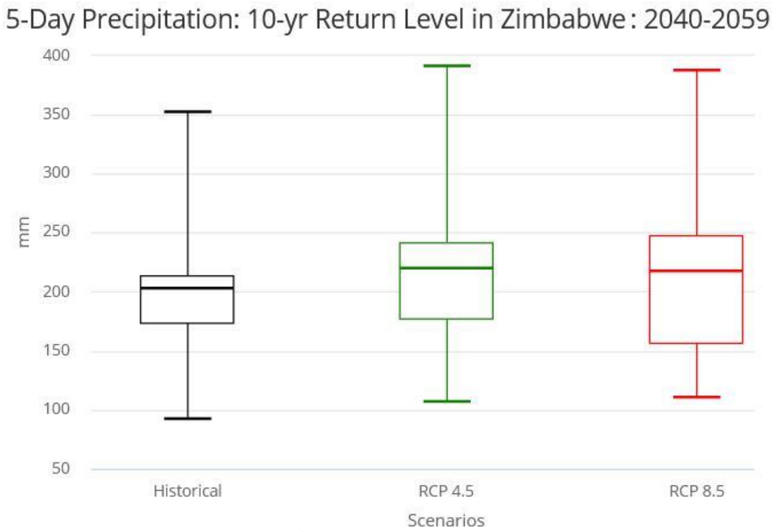


Figure 19: 5 day precipitation for the 10-yr return period in Zimbabwe

2.15 Mean Annual Temperature

Significant temperature rises are only noted from the 1980s where the increase is accelerated from around 2015 such that the period from the early 1980s to date has been the warmest in the instrument record. There is also evidence of an increase in the number of hotter and a decrease of colder days than before. For example, the frequency of cold nights and cold days has decreased by about 1.2 and 1.1% per decade respectively (that is a reduction of four (4) cold nights and 1 cold day less every ten years) from the 1971-1995 reference period. Warm day frequency has increased by about 1.9% per decade (that is about seven (7) warm days more every ten years). For the future, the inceases become even more rapid for the RCP 8.5 such that the temperature increase will on average be about 3.2 C for RCP 4.5 and 4 C for RCP 8.5 for the long term (figure 20).

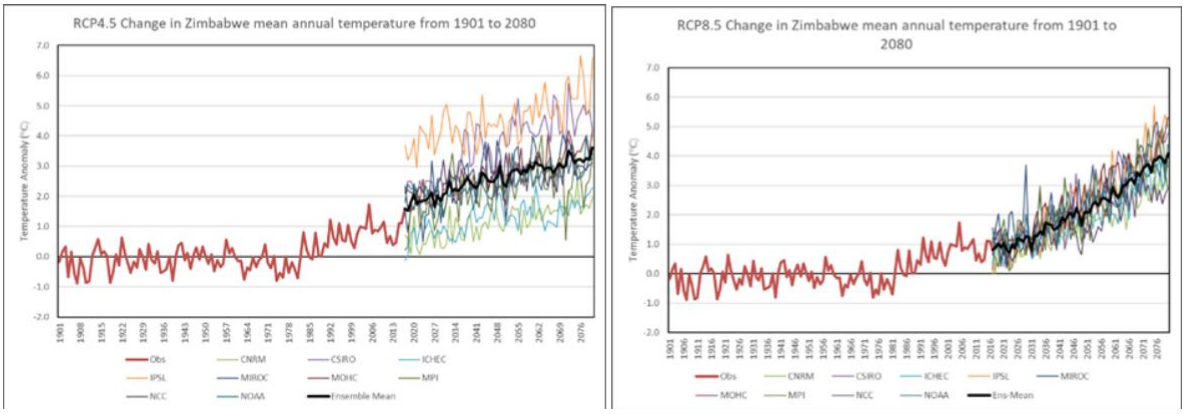


Figure 20: Temporal manifestation of Zimbabwe mean annual temperature for RCP 4.5 (left panel) and RCP 8.5 (right panel)

2.16 Future Spatial Changes in Temperature

The spatial changes in annual temperature for Zimbabwe are shown in figures 18 and 19 for RCP 4,5 and 8.5 respectively. These anomalies are presented relative to the baseline period which is presented in the first panel of figure 18. We observe that, generally, the spatial distribution of temperature increase is relatively homogeneous across the country, with slightly higher warming trend projected in southern and western parts of the country. Figure 18 shows that spatial distribution of the mean annual temperature for the near term (second panel), mid-term (third panel) and long term (forth panel) windows. The anomalies relative to the current (first panel) and are for the RCP 4.5 projections. The temperature increases are more than 1.1^0C across the country for all time frames though intensifying with time. These temperature increases are that their highest for the long term where we note more than 2^0C will be expected especially over the western half of the country.

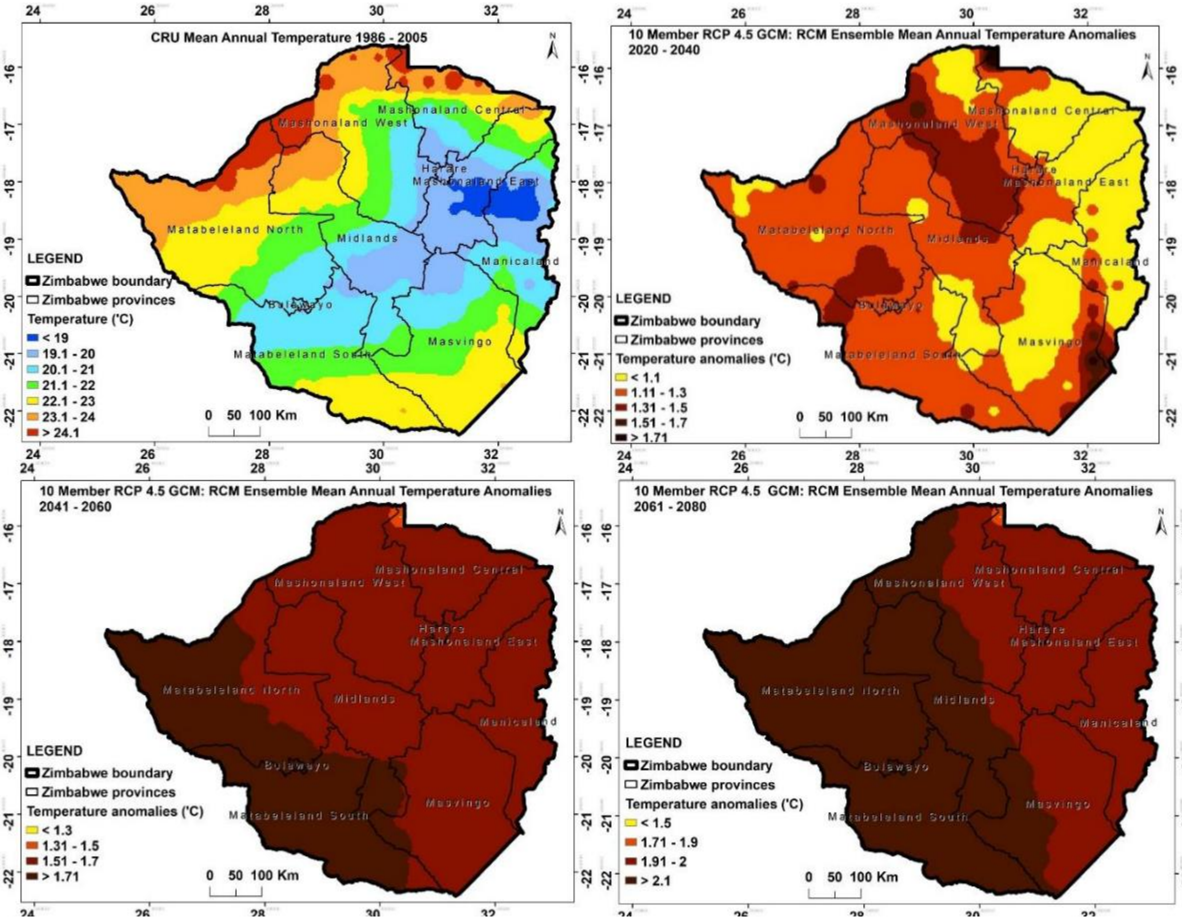


Figure 21: Spatial distribution for Zimbabwe mean annual temperature for the periods 1986-2005 (1st panel), 2020-2040 (2nd panel), 2041-2060 (3rd panel) and 2061-2080 (4th panel) for RCP 4.5

As expected with a higher greenhouse gas emission scenario of RCP 8.5, temperature increase progressively for each subsequent time window (figure 22). There is a projected warming of more than 1^{0}C for the near term increasing to more than 2^{0}C for the mid-term and displaying the warmest temperatures exceeding 3^{0}C in the long term period. For each time window, the projected increases are more intense for Matebeleland North and South including the southern parts of Midlands and Mashonaland East. For this emission scenario, Masvingo appears to have the least increases for all the time frames analysed.

It should be noted that the rising temperatures compared to baseline period are more prominent during summer, especially from September to December. This coincides with the rainfall season hence there will be enhanced evapotranspiration during this time of the year. The effect are to reduce the effective rainfall amounts which could have been received at a point, whilst at the same time changing the habitat conditions to suit plants and animals that can withstand higher temperatures.

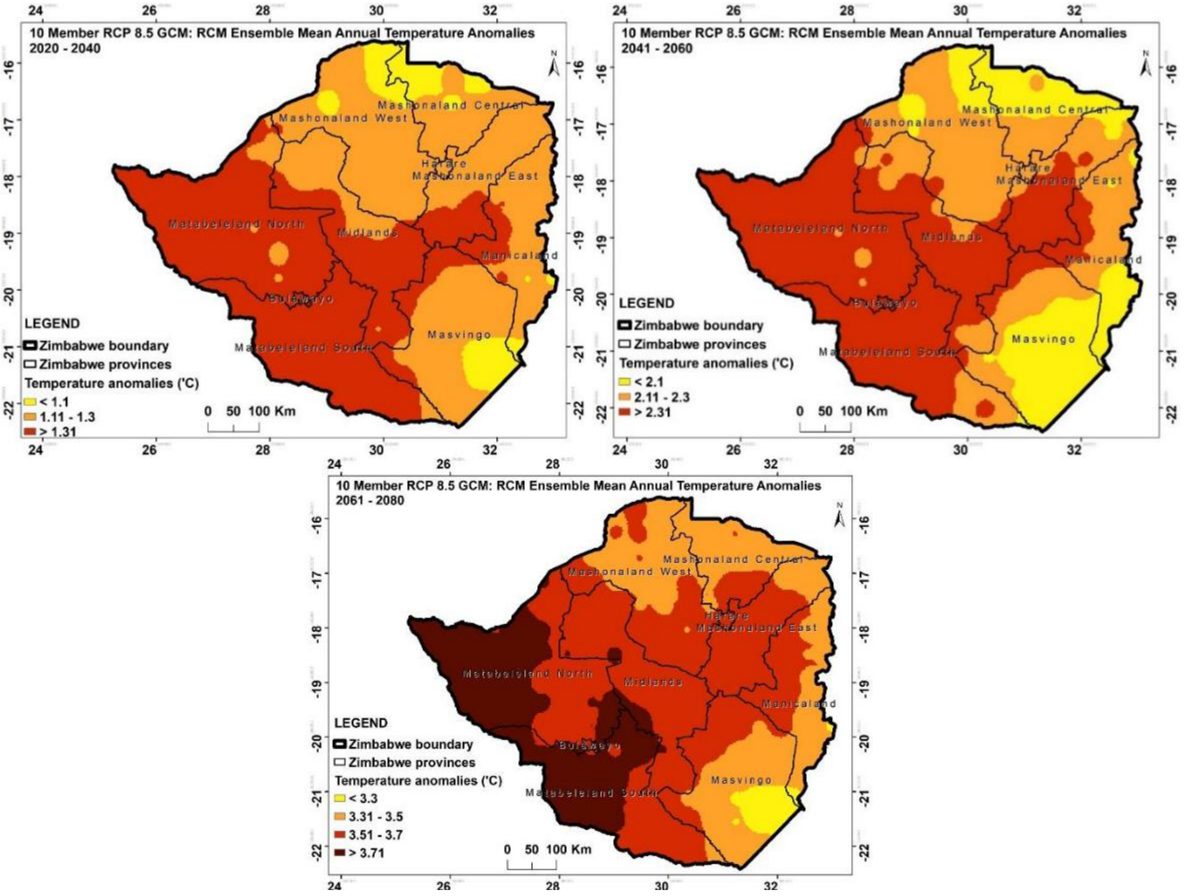


Figure 22: Spatial distribution of mean annual CRU rainfall Anomalies for the periods 2020-2040 (1st panel), 2041-2060 (2nd panel) and 2061-2080 (3rd panel) for RCP 4.5.

CHAPTER 3: VULNERABILITY ASSESSMENT IN ZIMBABWE

3.1 Climate hazards in Zimbabwe

The frequency of exposure to drought and floods were used to come up with the current exposure multihazard index. The results of drought and flood mapping are illustrated in figure 23 (a) and (b) respectively. It can be observed that drought prone regions of are characteristic of the south west and northern parts of the country and while those considered less prone are located in the northern central parts of the country. Based on flood probability, the most prone areas are located in the north east parts of the country and include Muzarabani and the southern districts of Beitbridge and Mwenezi which are generally known as flood prone areas.

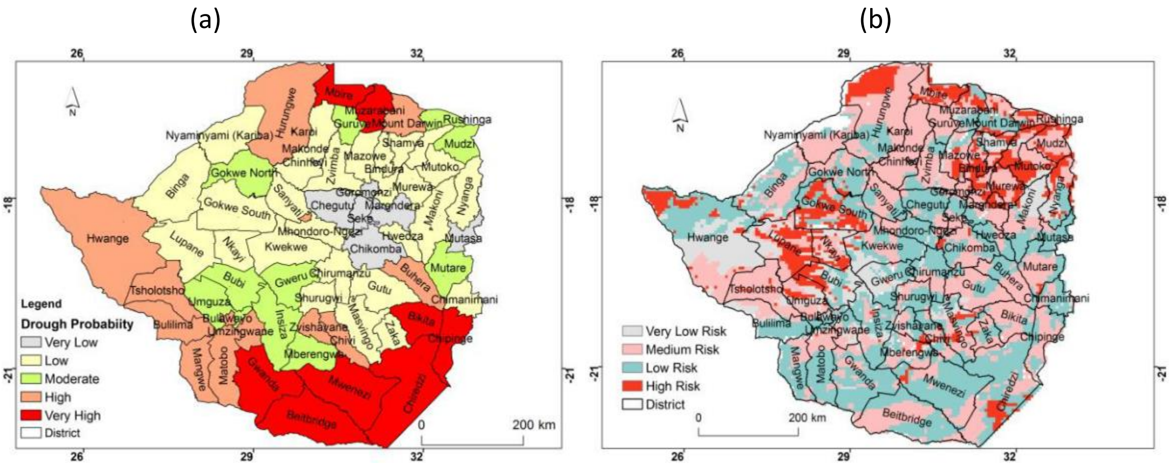


Figure 23: Climate hazard maps of Zimbabwe for (a) drought probability (b) flood probability.

The combined current exposure illustrated in figure 24 shows that the eastern regions have the least exposure whilst the central watershed had moderate exposure. The highest exposure is on the southern districts with the western districts including those along the Zambezi River displaying relatively high vulnerability.

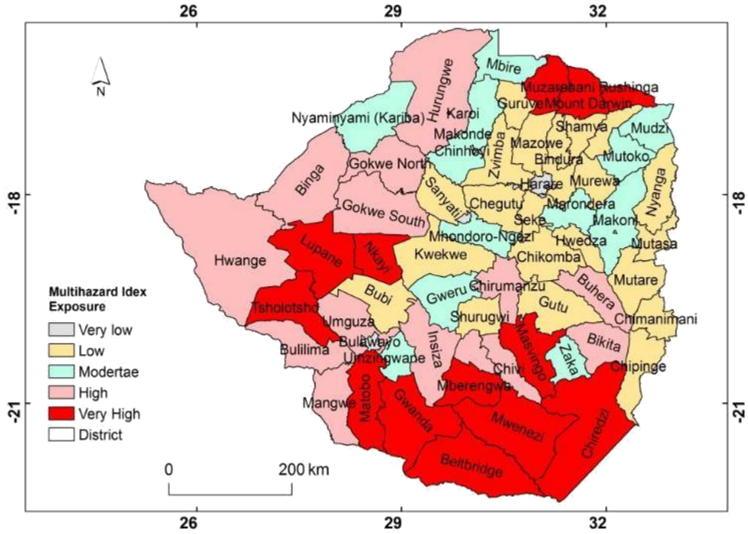


Figure 24: Spatial variation in exposure based on drought and flood hazard

3.2 Current Sensitivity and Adaptive Capacity

The sensitivity and adaptive capacity constitute the social vulnerability. The sensitivity index was calculated from district income, and poverty indices whilst the adaptive capacity was derived from literacy rate and infrastructural assets particularly accessibility to water. These were determined by stakeholders during the various workshops which were conducted throughout the country. According to these indicators, the districts with the highest sensitivity index are Binga, Kariba, Bubi and Murewa whilst some of those with the lowest sensitivity are Shamva and Bindura. Districts with high adaptive capacity are Gweru, Shurugwi and Lupane (figure 25, left panel) whilst those with the lowest values are Sanyati, Muzarabani and Hurungwe (figure 25, right panel). The values for current sensitivity and adaptive capacity were used to derive the current vulnerability.

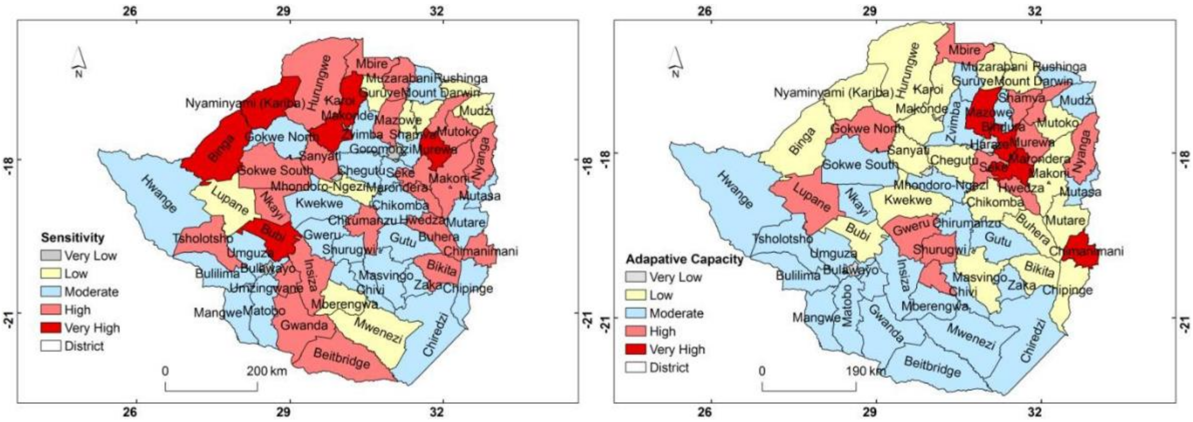


Figure 25: Spatial variation in current sensitivity (left panel) and adaptive capacity per district (right panel)

However, by using the four domiant vulnerability indices identified in figure 3 and also factoring in exposure, the final vulnerability index of Zimbabwe is presented in figure 26. This vulnerability index provides a single measure for climate change exposure, sensitivity and adaptive capacity. When spatially presented at district scale, this vulnerability map provides a visual representation of the categories of vulnerability that is range-based. The majority of the districts with a relatively high vulnerability form a cluster in the southern and south-eastern parts of the country. They are Beitbridge, Umguza, Insiza, Hwange, Mangwe and Chirumhanzu. These are locations where high sensitivity coincides with high hazard index values (drought prone areas) as depicted in figure 25. This puts these districts in a doubly disadvantageous position. It is also noted that in general, the central part of the country has low to moderate vulnerability.

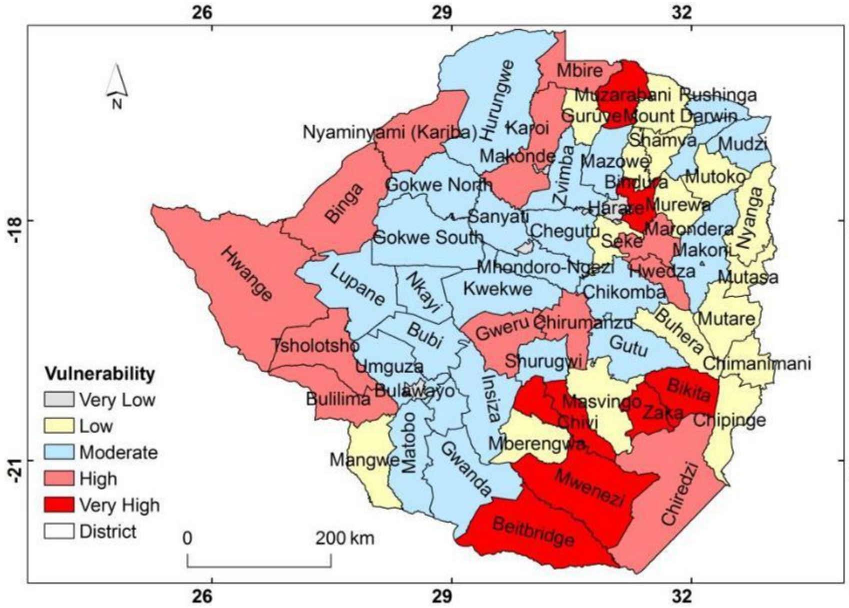


Figure 26: Spatial variation in vulnerability in Zimbabwe based on current climate

3.3 Climate Change Impacts at Provincial Level

Results of this study have indicated that seasonal and annual rainfall amount will decline and the number of rainy days will be fewer. In addition, we found that the seasons will be characterised by late onset and early secession of the rainfall that results in shrinking of seasons going into the future. The number of days of consecutive dry spells per year (or days without significant rainfall of at least 1mm) is projected to increase which may increase the frequency of droughts. Non-climatic factors such as unsustainable land use practices in the catchments such as deforestation, overgrazing, cultivation on steep slope, bush burning are causing land degradation which seems to be exacerbating the impacts of climate change across different regions in Zimbabwe.

In addition to rainfall changes, the number of hot days is projected to increase, whereas extreme cold days will significantly decrease especially in the western regions of the country. According to the World Bank (2015), increase in temperature may result in evapotranspiration increases and runoff declines. The recent IPCC Report (2018) projects that Zimbabwe may experience decrease in precipitation of about 10 to 20%, accompanied by longer dry spells. In general Zimbabwe is projected to be more exposed to extreme weather events such as droughts, heatwaves, heavy rains, flash floods, strong winds, hailstorms and tropical cyclones. An example of this is the recent Cyclone Idai, which affected more than 270,000 people in Zimbabwe in March 2019 and also the recent Tropical Cyclones Chalane and Eloise of December 2020 and January 2021 that resulted in infrastructural damage over the eastern and southern parts of the country.

To mitigate drought there is need to expand irrigation since approximately 80% of agricultural land lies in arid or semi-arid regions classified as NR III, IV and V. Irrigation, therefore, acts as a mitigating measure against droughts and mid-season dry spells. All these climate change impacts require water management adaptation measures. In the following section we describe the expected impact of climate change per province including the predominantly urban provinces of Bulawayo and Harare. The current changes are described first and then the climate projections. However, it must be noted that although consistent with the expected effects of climate change, none of these changes can be attributed specifically to the effects of climate change.

3.3.1 Manicaland Province

Manicaland province is characterised by all the agroecological regions with annual rainfall averaging 200- 1000mm. The perennial rivers of Wengezi and Umvumvu; Nyahode, Haroni, Gairezi, Nyangombe, Save, Odzi and Rusitu are found in this province. In terms of infrastructure, the roads in the eastern part are partially accessible during the rainy season and are not all-weather roads. The province is Zimbabwe's third-most densely populated province and second most populated province in Zimbabwe. The province has a huge tourism potential ranging from hot springs, mountain climbing, waterfalls, favourable weather conditions and rich cultural and heritage sites among others.

Climate Change projections under RCP 4.5 and RCP 8.5

The expected changes in precipitation and temperature may affect the rich biodiversity in the province through the introduction of invasive species. The impacts may include a shift in vegetation zones and biodiversity loss as the climate shifts to a drier and hotter one. The retreat of the vast majority of river sources may also affect water availability in downstream areas. Additional impacts include a reduced potential for tourism, as the tourist attraction centres like hot springs, waterfalls and trout fishing which thrives in cooler environments will disappear due to the changing climate. There will also be increased risks to infrastructure and settlements from floods particularly in lower lying regions, landslides and rock falls in some regions. The close proximity of the province to the Mozambique Channel provides the greatest risk to tropical cyclones whose generation will be enhanced due to projected warming of the ocean. Already Cyclone Idai negatively affected human lives and infrastructure in March 2019 with Tropical Storm Chalane and Eloise immediately following suit in December 2020 and January 2021.

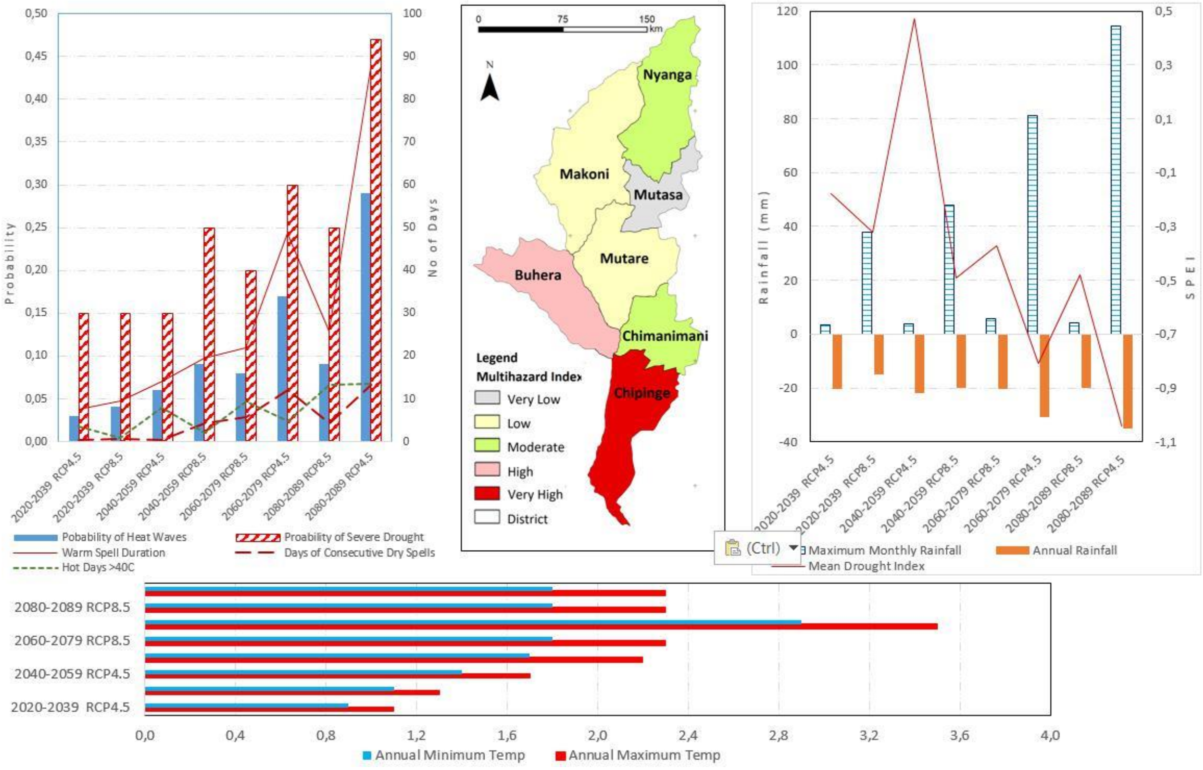


Figure 27**:** Projected Climate hazards and exposure to the hazards in Manicaland province *The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum*

temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI.

The first panel (left) represent projected climatic variables under RCP 4.5 and RCP 8.5 for heat waves probability, severe drought probability, warm spell duration, days of consecutive dry spells and very hot days greater than 40 °C. The panel to the right represents maximum monthly rainfall, rainfall season anomaly and mean droughts indices while the one at the bottom shows annual minimum and maximum temperature. The middle panel depicts the current climate hazard exposure for the district using a multi-hazard index.

The climate change impacts for Manicaland province are summarised in figure 28.

Climate Change Impacts for Manicaland Province

Main Landuse:

Forest plantations; state forests; commercial farming; game management areas, communal areas.

Climatic Risks/Hazards

Increase in: temperature, evapo –transpiration, extended season dry spells, frequency & severity of droughts, thermal ranges for biological organisms, incidents of intense rainfall, frequency & severity of floods, frequency & severity of droughts, frequency & severity of Cyclones, intra-seasonal rainfall characteristics

Settlements & Infrastructure

- Increase in infrastructural design costs,
- Damage of roads, bridges, rail road's & airport landings
- impacts on drainage sewerage systems
- accelerated deterioration of physical infrastructure facilities
- damage to housing & settlements
- damage to infrastructure facilities
- decline of water quality
- damages to critical social facilities: health, security, education & communication

Water & Energy

- Increase upstream erosion and silting on carrying capacities of dams
- Reduction in water for hydropower generation
- Scarcity of water reduces the generation of energy
- Physical damage of dam walls
- Decrease in availability of usable water
- Increase in water pollution
- Decline in fresh water supply
- Degradation of water quality
- Decreased amount of water for irrigation

Health

- Increase of vector borne diseases
- Increase in water borne diseases
- Severe malnutrition
- Increase in flood incidence, displacement
- Increased risk of spreading of existing vector borne-diseases (e.g. malaria)
- Increased risk spreading of pathogenic diseases
- Increased risk of new areas becoming susceptible to vector bone & pathogenic diseases
- Health and sanitation problems due to poor access to water
- Increased risk of diseases & ill-health conditions due to heat stress
- Increased incidences of malnutrition

Tourism and Recreation

- Reduction in scenic attractions & aesthetic value
- Decline in cultural assets
- Loss of recreational activities & opportunities
- limited access due to damaged roads & infrastructure
- increased tourist facilities affected by reduced availability of water & increased temperatures.
- adverse impacts on ecologically-sensitive tourist destinations
- increased risk for migration of wildlife populations
- increased risk for species extinction
- increased risk of damages to tourism infrastructure
- loss of recreational environment conducive for recreational activities.
- damages to monuments & archaeological assets
- creation of unsuitable conditions for recreation & travelling
- increased incidents of disaster situations unfavorable for tourist attraction

Agriculture

- Shortening of crop plant maturity period
- Expanding crop diseases
- Low productivity of soils & animals
- Increase in crop failure
- Decrease in livestock feed availability & quality
- Reduced animal health, growth & reproduction
- Increase in distribution of some infectious diseases
- Increased in decomposition rate of organic matter
- Contracting of pastoral zones across the country
- Increase in livestock death
- Increase in Human wildlife conflict
- Decrease in irrigation potential
- Water logging of fields and flooding of boreholes
- Reduction in dairy products from dairy farming
- Increased in human-wildlife conflict
- Reduction in irrigation potential of water bodies

Ecosystems & Biodiversity

- Expansion of tropical dry forests & the disappearance of mountain wet forests;
- Increased biodiversity loss
- Increased loss of indigenous species & decline of natural regeneration
- Expansion of toxic weeds
- Increased prevalence of forest fires,
- Increase in diseases & pests
- Increased physical damages to natural ecosystems
- increased mortality & stress on fauna
- Decline in ecosystems services
- reduced availability of water to surrounding areas
- Increase in risk of migration of wildlife population
- Higher risk of extinction of species
- Increased risk forest loss due to wild fires due to higher temperatures
- Decrease in structure and composition of natural ecosystems
- Decrease in spatial distribution of natural vegetation
- Increase in damage & decline on aquatic habitat & life forms
- Expansion of tropical dry forests & the disappearance of mountain wet forests;

Figure 28: District climate vulnerability of Manicaland Province and its related climate change impacts on the national priority economic sectors

3.3.2 Masvingo Province

Masvingo province is covered for a large part by the lowveld and the greater part of the province receives low and erratic rainfall. The province has a hydrological advantage of having large inland freshwater bodies in the country such as Lake Mutirikwi and Tokwe Mukosi. The province has a general high vulnerability index in most districts and is subject to seasonal droughts, with evidence of a series of droughts since 1992. Masvingo province has great potential in cattle ranching with the highest population of cattle in the country. In addition, it is endowed with tourism potential in form of national monuments, cultural heritage sites and major wildlife sanctuaries..

Climate Change projections under RCP 4.5 and RCP 8.5

In this province, crop growing seasons are becoming shorter, temperatures are rising, rainfall amounts are declining and mid-season droughts are also occurring more frequently. With the projected general decline in rainfall, the province may in the future receive rainfall amounts that will not able to support rainfed agriculture. In fact this has already manifested in the new NR Vb where the conditions are described to be unsuitable for any form of rain fed agriculture in the newly redefined agroecological zones (Manatsa et al., 2020). The province is also prone to the impacts of flood induced tropical cyclone. In the past these tropical cyclone such as Eline destroyed irrigation schemes in the province.

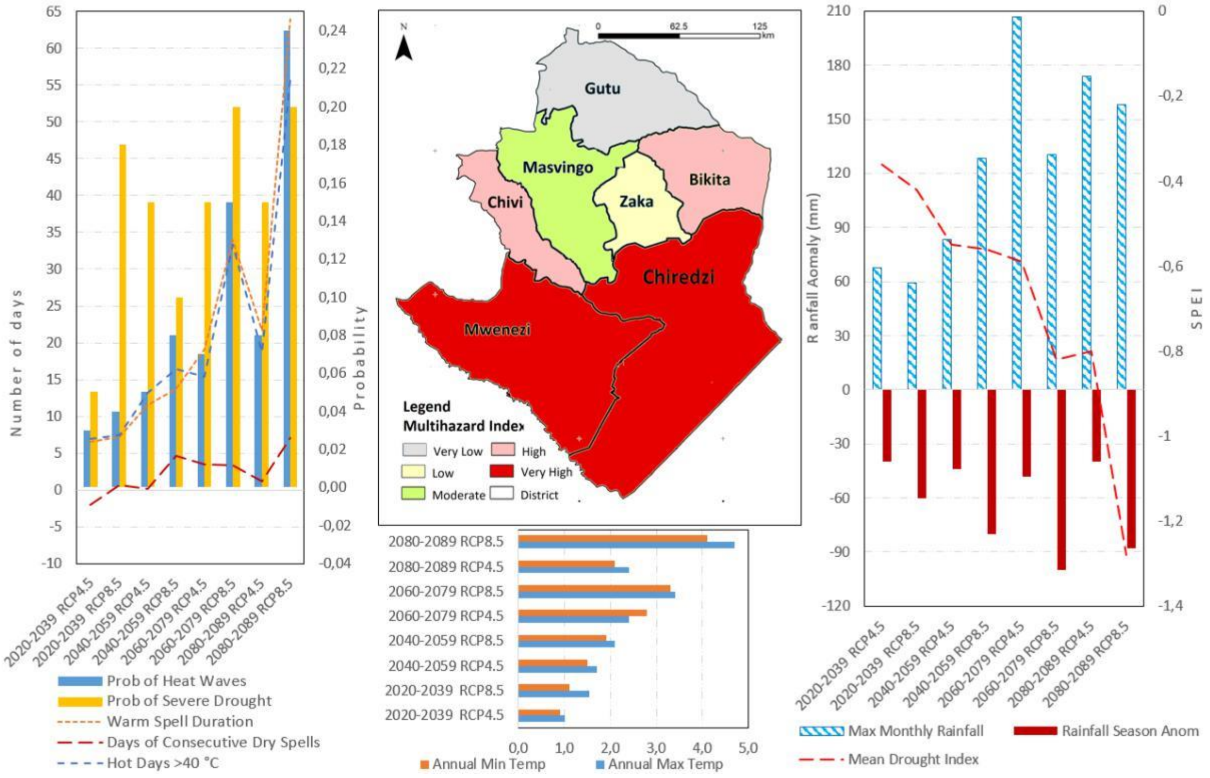


Figure 29: Projected Climate hazards and exposure to the hazards in Masvingo Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and *hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI*

The projected climatic variables using RCP 4.5 and RCP 8.5 for are illustrated in figure 29. The figure shows the probability of heat waves, severe drought, and warm spell duration, days of consecutive dry spells and very hot days greater than 40°C on the left panel. The right panel shows the maximum monthly rainfall, rainfall season anomaly and mean droughts indices while the bottom panel indicates the annual minimum and maximum temperature of the province. The second panel depicts the current climate hazard exposure for the district using a multi-hazard index. Figure 30 summarises the main climate change impacts in Masvingo province.

Related Climate Change Impacts for Masvingo Province

Landuse

Commercial farming areas
Communial areas, Sanctuary, Wildlife management arreas, cultural centers

Climatic Risks/Hazards

- Temperature increases
- Intensifying in drought events
- Shifts in seasonal characteristics towards more arid conditions
- Increase in extreme weather events
- Reduction in rainfall amounts
- Increase in extremes
- Lowering of water tables
- Increase in crop failure risk

Water & Energy

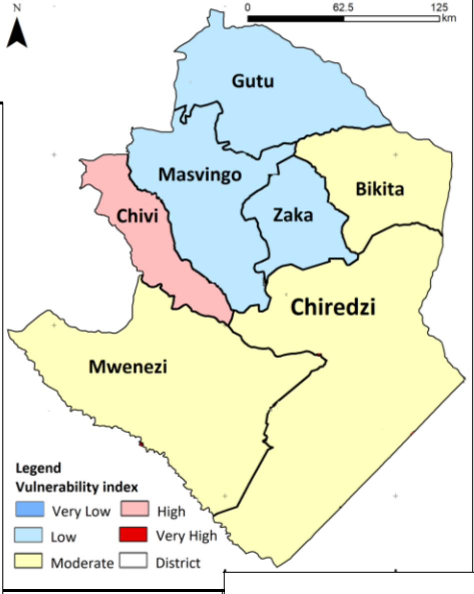
- Temperature rise larger than national average
- Increasing water demand for agriculture
- reduction in hydropower generation potential
- Increase in low or no river flow
- Reduction in hydropower generation
- Reduction in irrigation water availability
- Reduction in drinking water due to lowering of water tables
- Reduction in rainfall amounts
- Reduction in irrigation potential
- Increased non-perennial flow of most rivers
- Drying up of boreholes & wells
- Energy demand outstripping supply from limited hydropower generation
- Increased demand of energy for cooling

Settlements & infrastructure

- Increasing damage risk from rock falls and landslides
- Increase in dam failure risk
- Increased damage to communication and power lines
- Increase in damage to rural settlements
- Reduction in drinking water availability from boreholes & wells
- Increased damage to roads which are not climate proof

Health

- Increase of vector borne diseases
- Increase in water borne diseases
- Severe malnutrition
- Increase in flood incidence, displacement
- Decrease in drinking water availability
- Increased risk of spreading of existing vector borne-diseases (e.g. malaria)
- Increased risk spreading of pathogenic diseases
- Risk of new areas becoming susceptible to vector bone & pathogenic diseases
- Increased risk of new vector bone disease outbreaks
- Health and sanitation problems due to poor access to water
- Increased risk of diseases & ill-health conditions due to heat stress
- Increased incidences of malnutrition



Tourism and Recreation

- Reduction in tuorist arrivals
- Deterioration in asthetic values
- Increase in heavy precipitation events
- Reduction in water recreation facilities
- Increased biodiversity loss reduce tourism resources
- Increased bad weather reduce attractiveness of the tourism sites
- Reduction in cultural assets
- loss of recreational environment conducive for recreational activities.
- damages to monuments & archaeological assets
- creation of unsuitable conditions for recreation & travelling
- increased incidents of disaster situations unfavorable for tourist attraction
- Reduction in scenic attractions & aesthetic value

Agriculture

- Increased risks & reduced opportunities for fisheries
- Reduced crop yield & livestock production
- Increased damage to crops and livestock from weather extremes
- Significant reduction in frost risk to near zero probability
- Gradual replacement of arable land with rangeland
- Increased reduction in soil moisture
- Depletion of fodder during prolonged dry spells
- Reduction in carrying capacity of rangelands
- loss of draught oxen power
- increased animal & wild life mortality rate
- Deterioration in agro-ecological region classification

Ecosystems & Biodiversity

- High risk of species extinctions & biodiversity loss
- Increasing risk of forest pests & fires
- Increased loss of indigenous species & decline of natural regeneration
- Expansion of toxic weeds
- Increased thermal/heat stress on flora & fauna
- Migration of species due to water stress
- Physical damages to natural ecosystems
- Increased mortality & stress on fauna Increased risk forest loss due to wild fires due to higher temperatures
- Decrease in structure and composition of natural ecosystems
- Decrease in spatial distribution of natural vegetation

Figure 30: District climate vulnerability of Masvingo Province and its related climate change impacts on the national priority economic sectors

3.3.3 Matabeleland North Province

It is the largest province in the country by land size located on the edge of the Kalahari basin and is characterised by an arid climate with water scarcity being very common. The soils in most parts of the province are generally infertile and production of commercial crops is limited hence food insecurity is a characteristic feature of the area. The local economy of the province is dominated by agriculture particularly growing of drought tolerant crops such as sorghum and millet with huge potential for cattle ranching. The substantial wildlife population in the area presents huge tourism opportunities.

Climate Change projections under RCP 4.5 and RCP 8.5

The projected decline in rainfall means that water for both crops and animals will become a problem that may lead to the extinction of many large mammals on the protected zones if no adequate adaptation measures are adopted. The reduction in animal species in game parks will likely have a negative impact on the tourism industry. Tourist resort areas such as the Victoria Falls along the Zambezi river could also be negatively affected by the projected significant reduction in the river flows within its catchment. Growing of small grains may also be unsustainable as the climate will be too harsh for the survival of the crops. Cattle rearing will also be affected with the limitations in the provision of natural drinking water.

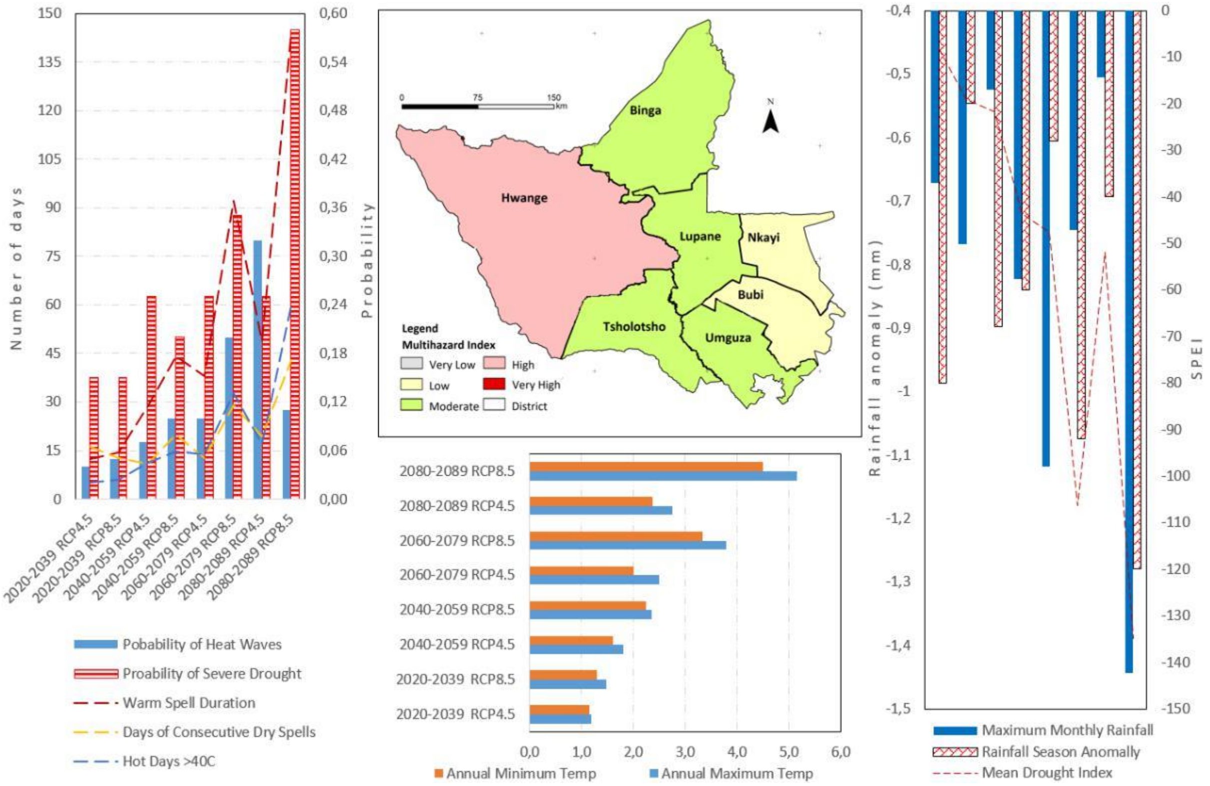


Figure 31: Projected Climate hazards and exposure to the hazards in Matabeleland North Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum *temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI*

The probability of projected climate hazards for Matabeleland North province using RCP 4.5 and RCP 8.5 are illustrated in figure 32. The left panel shows the probability of heat waves, severe drought, and warm spell duration, days of consecutive dry spells and very hot days greater than 40°C. The right panel shows maximum monthly rainfall, rainfall season anomaly and mean droughts indices while the bottom panel shows annual minimum and maximum temperature. The second panel depicts the current climate hazard exposure for the district using a multi-hazard index. The summary of climate change impacts for the province is illustrated in figure 32.

Climate Change Impacts

Main Land Use

Recreation, wildlife management,communal areas, commerical farming areas,fishing, sanctuary, country hot spot for 'Big Five' animals.

Climatic Risks/Hazards

- Temperature increases more than national average
- Intensifying in drought events
- Shifts in seasonal characteristics
- Increase in extremes
- Reduction in growing season
- Increased evapotranspiration
- Lowering of water tables
- Increase forest fire risk
- Increased intensity and frequency of hydro-climatic hazards

Settlements & Infrastructure

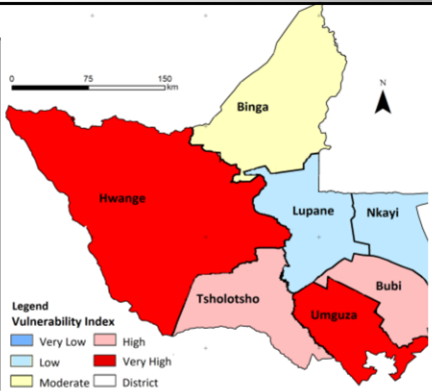
- Increased thermal stress on residents
- Accelerated deterioration of infrastructure facilities: e.g. thermal cracks
- Damage to housing & settlements
- Damage to infrastructure facilities
- Damages to critical social facilities: health, security, education, communication
- Increased landslide incidence threat to settlements & infrastructure
- Drying up of wells & boreholes

Water & Energy

- Temperature rise larger than national average
- High fluctuation of water availability in major/medium reservoirs
- Rapid dry out of minor irrigation facilities
- Poor and disturbed flow in streams
- Decreased quality of water due to high salinity of some aquifers
- Depletion of ground water sources
- Rapid siltation of reservoirs
- Damage to irrigation structures
- Damage to domestic and industrial water supply structures
- Lowering of water table beyond reach of most wells and boreholes

Health

- Increased risk of spreading of existing vector borne-diseases (e.g. malaria)
- Increased risk spreading of pathogenic diseases
- Risk of new areas becoming susceptible to vector bone & pathogenic diseases
- Increased risk of new vector bone disease outbreaks
- Health and sanitation problems due to poor access to water
- Increased risk of diseases & ill-health conditions due to heat stress
- Increased incidences of malnutrition



Tourism and Recreation

- Reduction in tuorist arrivals
- Deterioration in asthetic values
- Increase in hydro-meteorological disasters which may deter tourist visits
- Increase in multiple climatic hazards
- Increased biodiversity loss reduce tourist attraction environment
- Increased bad weather reduce attractiveness of the tourism sites
- Loss of aesthetic value of the environment

Agriculture

- Increased thermal/heat stress on crops
- Increase water stress on crops
- Regular shortages of water for extended periods
- Reduction of soil moisture
- Decreased soil quality & fertility
- Death, Increased communicable diseases,
- loss of livestock production and productivity
- decreased fish production, loss of pasture
- Increased thermal stress on doth domestic & wild animals
- Increased soil erosion from heavy rains
- Significant reduction in frost risk to near zero probability
- Drastic deterioration in fishing conditions, fish yield & catch variety
- Increased wildlife mortality
- Increased human wild life conflict
- Increased threat from invasive species invasion

Ecosystems & Biodiversity

- Increased thermal/heat stress on flora
- Increased thermal/heat stress on fauna
- Changes in structure and composition of natural ecosystems
- Changes in spatial distribution of natural vegetation
- Drying out of wetlands and streams due to increased evapotranspiration
- Eutrophication of water bodies & wetlands
- Migration of species to more favourable habitats away from hostile environment
- Migration of species due to water stress
- Physical damages to natural ecosystems
- Increased mortality and stress on fauna

Figure 32: District climate vulnerability of Matabeleland North Province and its related climate change impacts on the national priority economic sectors

3.3.4 Matabeleland South

Matabeleland South is the least populous and second-least densely populated province in the country. It is located around the edge of the Kalahari basin and is characterised by erratic rainfall patterns. The economy of the province is largely subsistence crop production and livestock farming. However, droughts and limited economic opportunities characterise the province, with arid and very dry conditions in agro- ecological regions 1V and V (a & b). A notable observation is that the province is endowed with a wide range of natural resources. Livestock farming is the most economically viable activity in the province where farmers produce high quality indigenous and exotic, cattle and goat breeds. Although this semi-arid province is most ideal for extensive livestock husbandry, animal performance remains subdued owing to numerous interactive factors, chief among them being diseases and poor health management. These are largely controlled by climatic factors. Crop production is dominated by small grains such as millet and sorghum. However the actual production is restricted by low and poorly-distributed rains coupled with recurrent droughts making livestock husbandry of greater importance to food security.

Climate Change projections under RCP 4.5 and RCP 8.5

Projected rising temperature rainfall decline are major challenges for Matabeleland South. This will result in a reduction of water to effectively sustain livestock production, wildlife and future irrigation schemes.

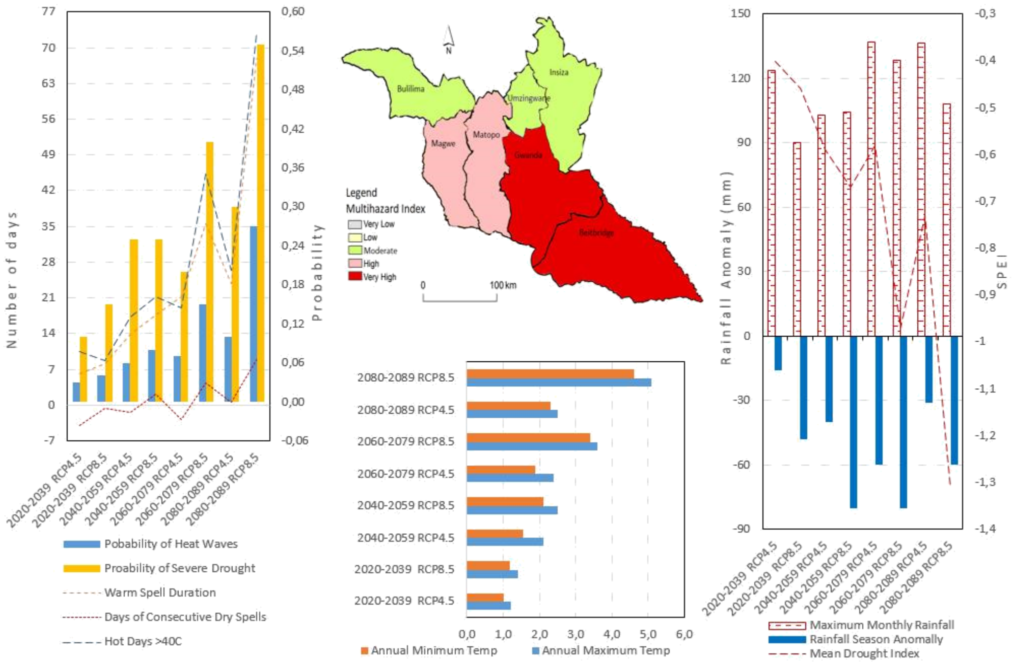


Figure 33: Projected Climate hazards and exposure to the hazards in Matabeleland South Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI

Figure 33 shows the projected climatic variables using RCP 4.5 and RCP 8.5 for Matebeleland South province. The shows the probability of heat waves , severe drought, warm spell duration, days of consecutive dry spells and very hot das greater than 40 °C. The maximum monthly rainfall, rainfall season anomaly and mean droughts indices are illustrated on the right pane while the bottom panel shows the annual minimum and maximum temperature. The second panel depicts the current climate hazard exposure for the district using a multi-hazard index.

Related Climate Change Impacts for Matabeleland South

Landuse

Commercial farming areas

Communial areas, Sanctuary, Wildlife management arreas, cultural centers

Climatic Risks/Hazards

- Temperature increases
- Intensifying in drought events
- Shifts in seasonal characteristics towards more arid conditions
- Increase in extreme weather events
- Reduction in rainfall amounts
-

Settlements & infrastructure

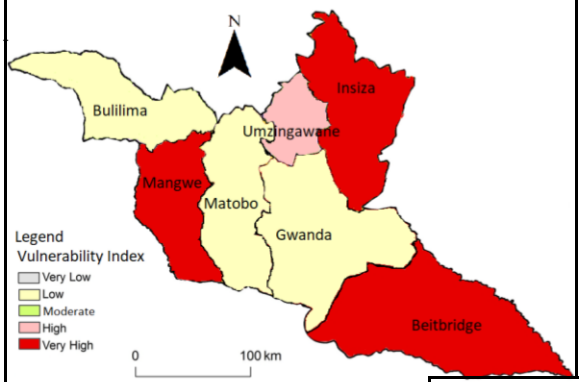
- Increasing damage risk from rock falls & landslides
- Increase in dam wall failure risk
- Increase in damage to roads
- Increased damage to communication & power lines
- Increase in damage to rural settlements
- Increasing damage risk from summer storms
- Increased damage from summer storms
- Destruction of road networks to markets

Water & Energy

- Temperature rise larger than national average
- High fluctuation of water availability in major/medium reservoirs
- Rapid dry out of minor irrigation facilities
- Poor and disturbed flow in streams
- Decreased quality of water due to high salinity of some aquifers
- Lowering of water table beyond reach of most wells and boreholes
- Reduction in irrigation potential
- Depletion of ground water sources
- Damage to irrigation structures
- Rapid siltation of reservoirs

Health

- Increased in human mortality due to heat waves
- risk of spreading of existing vector borne-diseases (e.g. malaria)
- Increased risk spreading of pathogenic diseases
- Risk of new areas becoming susceptible to vector bone & pathogenic diseases
- Increased risk of new vector bone disease outbreaks
- Health and sanitation problems due to poor access to water
- Increased risk of diseases & ill-health conditions due to heat stress
- Increased incidences of malnutrition due to higher risk of food insecurity



Tourism and Recreation

- Deterioration of cultural centres
- Migration of wild animals
- Reduction in scenic attractions & aesthetic value
- Loss of recreational activities & opportunities
- limited access due to damaged roads & infrastructure
- increased tourist facilities affected by reduced availability of water & increased temperatures.
- adverse impacts on ecologically-sensitive tourist destinations
- increased risk for species extinction
- loss of recreational environment conducive for recreational activities.
- damages to monuments & archaeological asset
- increased incidents of disaster situations unfavorable for tourist attraction

Agriculture

- Significant reduction in frost risk to near zero probability
- Displacement of arable land with rangeland
- Increased livestock & wildlife diseases &mortality
- Increase risk of invasive plant species
- Reduction in irrigation potential
- Loss of soil fertility from erosion of top soil & moisture from evapotranspiration
- Deterioration in agroecological suitability to rain fed agriculture
- Increased thermal/heat and water stress on crops
- Increased frequency of water shortage for extended periods
- Reduction of soil moisture, quality & fertility
- loss of livestock production and productivity including draught power decreased fish production, loss of pasture
- Increased thermal stress on doth domestic & wild animals
- Significant reduction in frost risk to near zero probability
- Drastic deterioration in fishing conditions, fish yield & catch variety
- Increased human wild life conflict
- Increased threat of pastures from poisonous invasive species invasion

Ecosystems & Biodiversity

- Increased thermal/heat stress on flora and fauna
- Changes in structure and composition of natural ecosystems
- Changes in spatial distribution of natural vegetation
- Drying out of wetlands and streams due to increased evapotranspiration
- Eutrophication of water bodies & wetlands
- Migration of species to more favourable habitats away from hostile environment
- Migration of species due to water stress
- Physical damages to natural ecosystems
- Increased extinction of animal & species
- Loss of wetlands & riverine ecosystems
- Increasing risk of biodiversity loss
- Increasing risk of forest fires
- High risk of species extinctions
- Increasing risk of forest pests
- Loss of biodiversity

3.3.5 Midlands Province

The economy of this province is centred on crop and livestock production, with the third highest herd of cattle in the country and up to thirty irrigation schemes. The province falls under agro-ecological zones II to V, with conducive warm to mild temperatures all year round. There is an unsatisfied demand for dairy and other agricultural products in the province, including richly endowed natural resources and cultural heritage and monuments. The unsatisfied demand for dairy and other agricultural products makes the province most ideal destination for investment in agriculture.

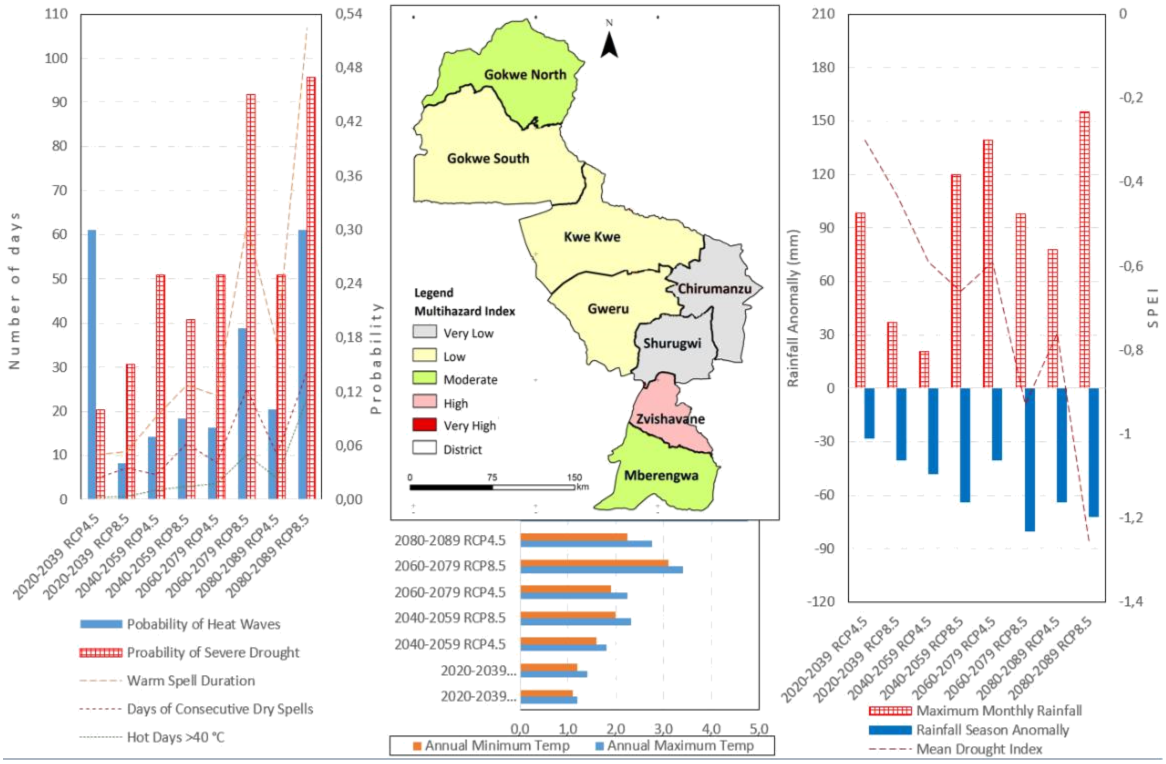


Figure 34: Projected Climate hazards and exposure to the hazards in Midlands Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI

Climate Change projections under RCP 4.5 and RCP 8.5

Since the primary economic activity for Midlands is agriculture based on both irrigation and rainfed, the expected future changes in the climate will adversely affect the province. Rainfall is projected to significantly decline under the background of rapidly warming climate, hence significantly reducing the capacity to nourish agriculture through both rainfed and irrigation (figure 35). The economic dependence on a small number of products and services (e.g. agriculture) make them highly vulnerable to any potential changes.

Climate Change Impacts for Midlands Province

Main Land Use

Wildlife Management Area, Recreation, Communial, Commerial Farming , Sanctuary

Climatic Risks/Hazards

- Temperature increases
- Intensifying in drought events
- Shifts in seasonal characteristics
- Shortening of growing season length
- Increase in climate extremes

Water & Energy

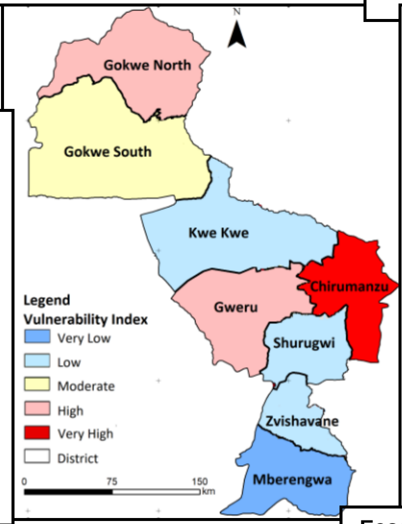
- Temperature rise larger than national average
- Increasing water demand for agriculture
- reduction in hydropower generation potential
- Increase in low or no river flow
- Reduction in hydropower generation
- Reduction in irrigation water availability
- Reduction in drinking water due to lowering of water tables
- Reduction in rainfall amounts
- Reduction in irrigation potential
- Increased non-perennial flow of most rivers
- Drying up of boreholes & wells
- Energy demand outstripping supply from limited hydropower generation
- Increased demand of energy for cooling

Settlements & infrastructure

- Damage to housing and settlements
- Damage to infrastructure facilities
- Decline of water quality
- Damage to roads and bridges
- Damages to critical social facilities: health, security, education, communication
- Increase in dam failure

Health

- Increased risk of spreading of existing vector borne-diseases (e.g. malaria)
- Increased risk spreading of pathogenic diseases
- Risk of new areas becoming susceptible to vector bone & pathogenic diseases
- Increased risk of new vector bone disease outbreaks
- Health and sanitation problems due to poor access to water
- Increased risk of diseases & ill-health conditions due to heat stress
- Increased incidences of malnutrition



Tourism and Recreation

- Reduction in scenic attractions & aesthetic value
- Decline in cultural assets
- Loss of recreational activities & opportunities
- limited access due to damaged roads & infrastructure
- increased tourist facilities affected by reduced availability of water & increased temperatures.
- adverse impacts on ecologically-sensitive tourist destinations
- increased risk for species extinction
- increased risk of damages to tourism infrastructure
- loss of recreational environment conducive for recreational activities.
- damages to monuments & archaeological assets
- creation of unsuitable conditions for recreation & travelling
- increased incidents of disaster situations unfavorable for tourist attraction

Agriculture

- Shortening of crop plant maturity period
- Expanding crop diseases & increase in crop failure
- Low productivity of soils & animals
- Shrinking of arable land area that is replaced by rangeland
- Decrease in livestock feed availability & quality
- Reduced animal health, growth & reproduction
- Increase in distribution of some infectious diseases
- Deterioration in Agroecological region characteristics
- Contracting of pastoral zones across the province
- Increase in livestock death
- Decrease in availability of livestock drinking water during droughts & dry season
- Decrease in irrigation potential
- Gradual replacement of arable land with rangeland
- Deterioration of Agroecological suitability for farming activities

Ecosystems & Biodiversity

- Increased biodiversity loss
- Increased loss of indigenous species
- Decline of natural regeneration
- Expansion of toxic weeds
- Increased prevalence of forest fires,
- Increase in diseases, pests

Figure 35: Projected Climate hazards and exposure to the hazards in Midlands Province

3.3.6 Mashonaland East Province

Mashonaland East has significantly favourable climate with good soils, the greater part of which is located in region II and engaged in intensive farming. Rainfall ranges from 750-1000mm and temperatures averaging 25-30 degrees Celsius, including abundant water bodies to agro-activities in-terms of irrigation of crops, livestock and pastureland. The province is highly engaged in agriculture and horticulture, with high production of wheat tobacco, maize, soya beans, fruits, vegetables, groundnuts, honey, sunflower, and livestock. One unique feature of the province is wine production and processing. Mashonaland East has great potential in tourism with resorts dotted around the province.

Related Climate Change projections under RCP 4.5 and RCP 8.5

Mashonaland East province is projected to experience decreasing precipitation and increasing temperatures particularly in summer (figure 36). The main impacts are decreases in water availability and crop yields, increasing risk of droughts and forest fires, biodiversity loss and adverse impacts on human health and well-being and on livestock. Environmental water flows, which are important for aquatic ecosystems, are threatened by climate change and by socioeconomic development. The observed invasion of rangelands by alien species is partly due to the increase in temperature. The suitability for tourism will decline markedly during key summer months, as temperature sore beyond the current comfort levels for international tourists. The region is a hotspot of climate change impacts, having the highest number of economic sectors that are bound to be severely affected.

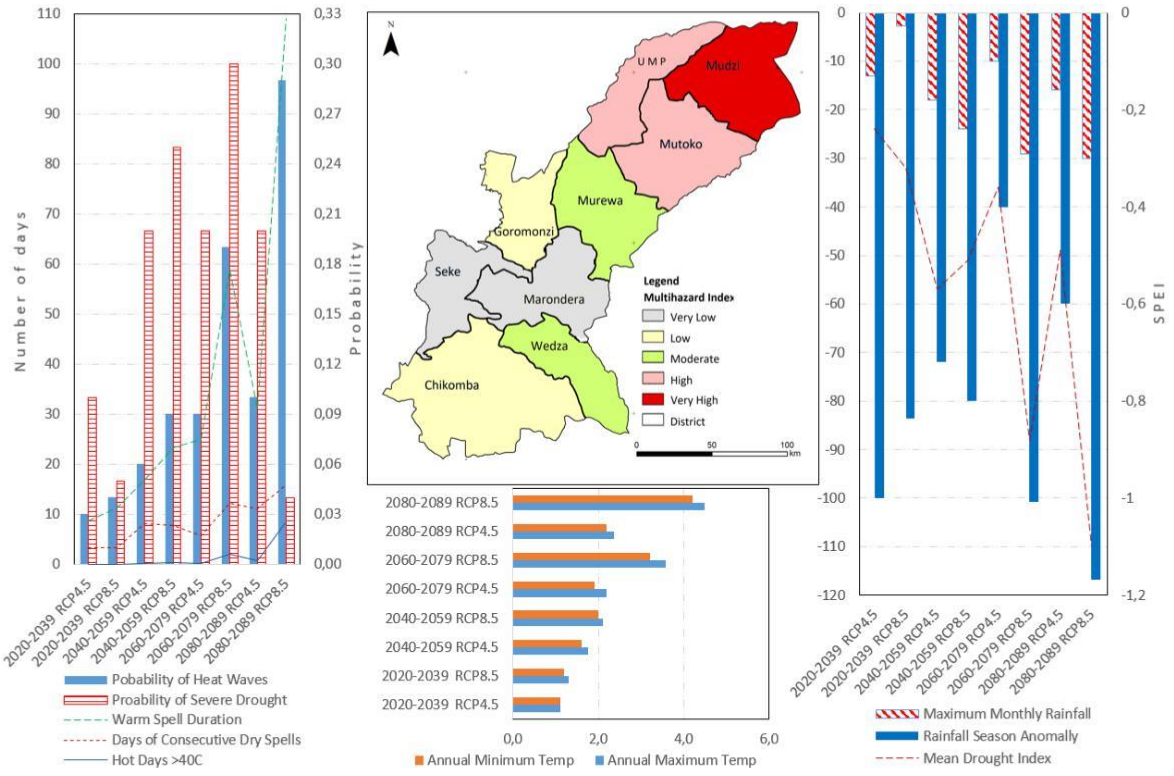


Figure 36: Projected Climate hazards and exposure to the hazards in Mashonaland east Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat *waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI*

The main climatic hazards and their future occurrence in Mashonaland East Province are illustrated in figure 36. The left panel illustrates heat waves probability, severe drought probability, warm spell duration, days of consecutive dry spells and very hot das greater than 40°C while the right panel shows the maximum monthly rainfall, rainfall season anomaly and mean droughts indices. The annual minimum and maximum temperature are illustrated at the bottom panel. The second panel depicts the current climate hazard exposure for the district using a multi-hazard index. The climate related impacts are illustrated in figure 37.

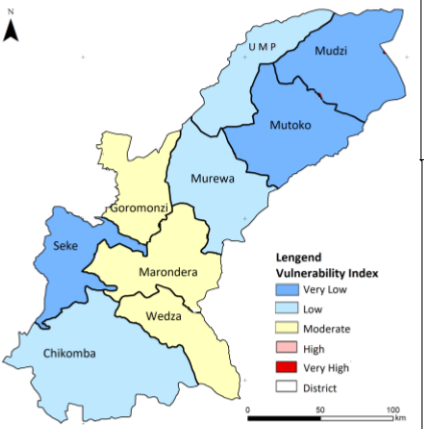
Related Climate Change Impacts for Mashonaland East

Main Landuse:
Forest plantations; state forests; commercial farming; game management areas, communal areas.

Climatic Risks/Hazards
- Increase in temperature & evapotranspiration
- extended dry spells,
- frequency & severity of droughts,
- exceedence of thermal ranges for biological organisms
- Increased intensity and frequency of extreme events
- Increased frequency & severity of tropical Cyclones,
- Changes in intra-seasonal rainfall

Settlements & Infrastructure
- Increase in infrastructural design costs,
- Damage of roads, bridges, rail road's and airport landings
- increased demand for health & sanitation facilities
- flooding of structures & settlements in low lying areas
- incidences of diseases & injury
- demand for health & sanitation facilities
- living comfort risk
- risks from collapse, declining health of buildings
- loss of value, due to more frequent & heavier rain events
- safety risks associated with existing buildings that do not meet standards & codes

Health
- Increase of vector borne diseases
- Increase in water borne diseases
- Severe malnutrition due to persistent crop failure
- Increase in flood incidence & displacement of communities especially the vulnerable
- Increased heat stress from frequent heat waves and elevated temperatures



Water & Energy
- Upstream degradation of natural resources results in increased silting of inland dams
- Scarcity of water reduces the generation of hydropower energy
- increased physical damage of dams
- Decrease in availability of potable water
- Increase in water pollution
- Decline in water supply due to reduced carrying capacity of water bodies
- Degradation of water quality, decreased hydroelectric power, Decreased amount of water for irrigation, Destruction of physical structures & roads from eroding power of running water

Tourism and Recreation
- Reduction in tuorist arrivals
- Deterioration in asthetic values
- Increase in heavy precipitation events
- Increase in multiple climatic hazards
- Increased biodiversity loss reduce tourism resources
- Increased bad weather reduce attractiveness of the tourism sites

Agriculture
- Shortening of crop plant maturity period
- Expanding crop diseases
- Low productivity of soils & animals
- Increase in crop failure
- Decrease in livestock feed availability & quality
- Reduced animal health, growth & reproduction
- Increase in distribution of some infectious diseases
- Increased in decomposition rate of organic matter
- Contracting of pastoral zones across the country
- Increase in livestock death
- Increase in Human wildlife conflict
- Decrease in irrigation potential
- Increases in tick-borne & Theileriosis (popularly known as January disease)diseases for cattle
- Reduction in dairy farming & dairy products

Ecosystems & Biodiversity
- Expansion of tropical dry forests & the disappearance of mountain wet forests;
- Increased biodiversity loss
- Increased loss of indigenous species
- Decline of natural regeneration
- Expansion of toxic weeds
- Increased prevalence of forest fires,
- Increase in diseases & pests
- Increased degradation of environment
- Increase in damage & decline on aquatic habitat & life forms
- Increase in invasive plant species

Figure 37: Projected Climate hazards and exposure to the hazards in Mashonaland East Province

3.3.7 Mashonaland Central Province

The province falls under four agro ecological regions II and III, IV and V. Regions II and III are mostly suitable for crop production. Major crops grown in the province include maize, cotton, tobacco, soya bean, citrus, small grains, livestock and wildlife. The rainfall pattern in the province ranges between 750 -1 000 mm per annum with the the Zambezi valley receiving the least amount of rainfall. . The province is generally favourable for agriculture although there are some areas that are prone to both droughts and floods like the Muzarabani district. There is evidence of abundant water bodies that are currently underutilised and great potential for tourism from diverse wildlife and scenic views to enjoy nature, including abundant indigenous fruits.

Climate Change projections under RCP 4.5 and RCP 8.5

Although the climate of the province is largely diverse the projected accelerated warming and reduction in annual rainfall may in semi-arid conditions covering the larger part of the province. Thus increasing heat extremes are a key hazard in Mashonaland Central (Figure 38). Hence together with reduced summer precipitation, increase drought and health risks become a reality.

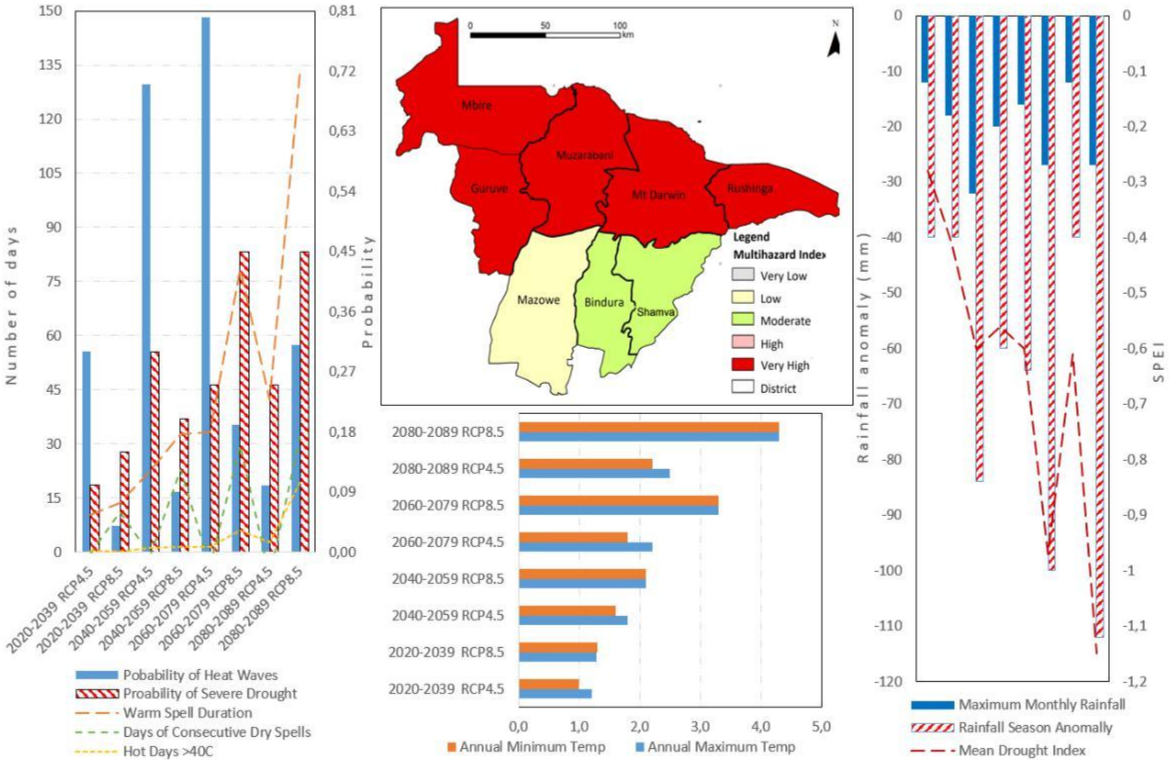


Figure 38: Projected Climate hazards and exposure to the hazards in Mashonaland Central Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI

Climate Change Impacts in Mashonaland Central

Settlements & infrastructure

- Damage to housing and settlements
- Damage to infrastructure facilities
- Decline of water quality
- Damages to critical social facilities: health, security, education, communication
- Destruction of physical structures & roads
- Destruction of dams, loss
- Increased incidences of landslides Destruction of physical structures & roads
- increased risk of dam failure
- increased incidences of landslides
- Increasing damage risk from storms

Main Land Use

Recreation, wildlife management,communal areas, commerical farming areas,fishing, sanctuary, country hot spot for 'Big Five' animals.

Climatic Risks/Hazards

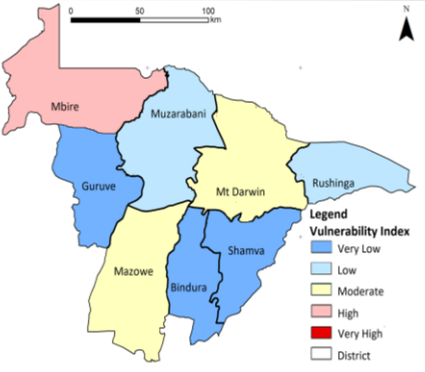
- Temperature increases more than national average
- Intensifying in drought events
- Shifts in seasonal characteristics
- Increase in extremes
- Reduction in growing season
- Increased evapotranspiration
- Lowering of water tables
- Increased intensity & frequency of tropical cyclones
- Shortening of growing season
- Reduction in seasonal rainfall amount

Water & Energy

- Decrease in hydropower potential due to low flows
- Decrease in water volumes in water bodies
- Lowering of water tables beyond reach of most boreholes and wells
- Energy demand outstripping that from reduced hydropower generation
- Upstream siltation reducing the water carrying capacity of water bodies & major dams
- Reduced irrigation potential
- Increased energy demand for cooling in summer reduction demand for heating in winter

Health

- microbes are expected to thrive better in a warmer world and higher rainfall will create the conditions for water borne vectors to flourish. Increased risk of spreading of existing vector borne-diseases (e.g. malaria)
- Increased risk spreading of pathogenic diseases
- Risk of new areas becoming susceptible to vector bone & pathogenic diseases
- Increased risk of new vector bone disease outbreaks
- Health and sanitation problems due to poor access to water
- Increased risk of diseases & ill-health conditions due to heat stress
- Increased incidences of malnutrition
- decrease of productive human power



Tourism and Recreation

- Reduction in scenic attractions & aesthetic value
- Decline in cultural assets
- Loss of recreational activities & opportunities
- limited access due to damaged roads & infrastructure
- increased tourist facilities affected by reduced availability of water & increased temperatures.
- adverse impacts on ecologically-sensitive tourist destinations
- increased risk for migration of wildlife populations
- increased risk for species extinction
- increased risk of damages to tourism

Agriculture

Increased thermal/heat stress on crops & on animals
Increase water stress on crops & decrease in irrigation potential
Decrease in water availability in reservoirs leading to suppressed irrigation potential
Increased soil erosion & reduction of soil moisture & quality
Increased threats to flood plain farming due to low persistent flows
Decreased livestock production and productivity
Reduction of grazing land area and loss of draught oxen power
Increased risk of pest and disease attacks on crops
Increased risk of parasite and disease attacks on livestock
Decreased food production & loss of cultivable land
Loss of pasture and water which results in wild animal migration,
Changes in dates of flowering of crops
Shrinking pasture availability for livestock
Increased susceptibility of crops & livestock to floods & drought hazards
Increased damage of fields from landslides
Reduced drainage and water logging problems
Decrease in crop yields & varieties

Ecosystems & Biodiversity

- Increased loss of indigenous species
- Decline of natural vegetation regeneration
- Expansion of toxic weeds
- High risk of species extinctions
- Increasing risk of forest pests & diseases
- Increase forest fire risk
- High risk of migration of wild animals due to loss of pasture & drinking water
- Increase in risk of invasive species
- Destruction of indigenous forests
- Increased soil erosion
- Increased land degradation
- Disappearance of riverine ecosystems
- Reduction in fish, plant & animals species

Figure 39: Projected Climate hazards and exposure to the hazards in Mashonaland Central Province

3.6.8 Mashonaland West Province

Mashonaland West has the highest number of inland dams including the Lake Kariba. These offer huge opportunities for irrigation, fish farming and water sport. The climate and soils are conducive for growing any type of crop. Crops grown in the province include maize & maize seed, tobacco, wheat, cotton, soya bean & soya bean seed, including horticultural Products such as flowers, peas, green beans, chillies, tomatoes, onions, potatoes, among others. The province also has great potential for tourism activities due to abundant heritage sites. It occupies the greater part of Lower Zambezi Valley which is a protected area. This includes the Mana Pools National Park, and the Chewore, Charara, Hurungwe, Dande, Doma Safari areas and is designated as a World Heritage Site by UNESCO. It is an important bird area and biosphere reserve which represents a source habitat for many populations of wildlife species, including the ‘Big Five’.

Climate Change projections under RCP 4.5 and RCP 8.5

Projections for the near future suggest that although there will be higher than average temperature increase, annual precipitation and river flows are likely to increase. Heavy precipitation events are projected to increase, leading to increased urban floods and associated impacts. In this way, climate change in the near future could offer some opportunities in this province, including increased crop variety and yields, enhanced forest growth, lower energy consumption for heating and possibly more summer tourism. However, more frequent and intense extreme weather events for the mid to long term periods are expected to have an adverse impact on the region, for example by making crop yields more variable and by increasing the risk from forest pests and forest fires. The projected persistent droughts in the long term that will exacerbate by increased evapotranspiration (Figure 40). This will make the country’s staple crop, maize that is grown in abundance in this province and is particularly vulnerable due to its intolerance to drought to have its yield drastically reduced, hence will likely exacerbate food insecurity.

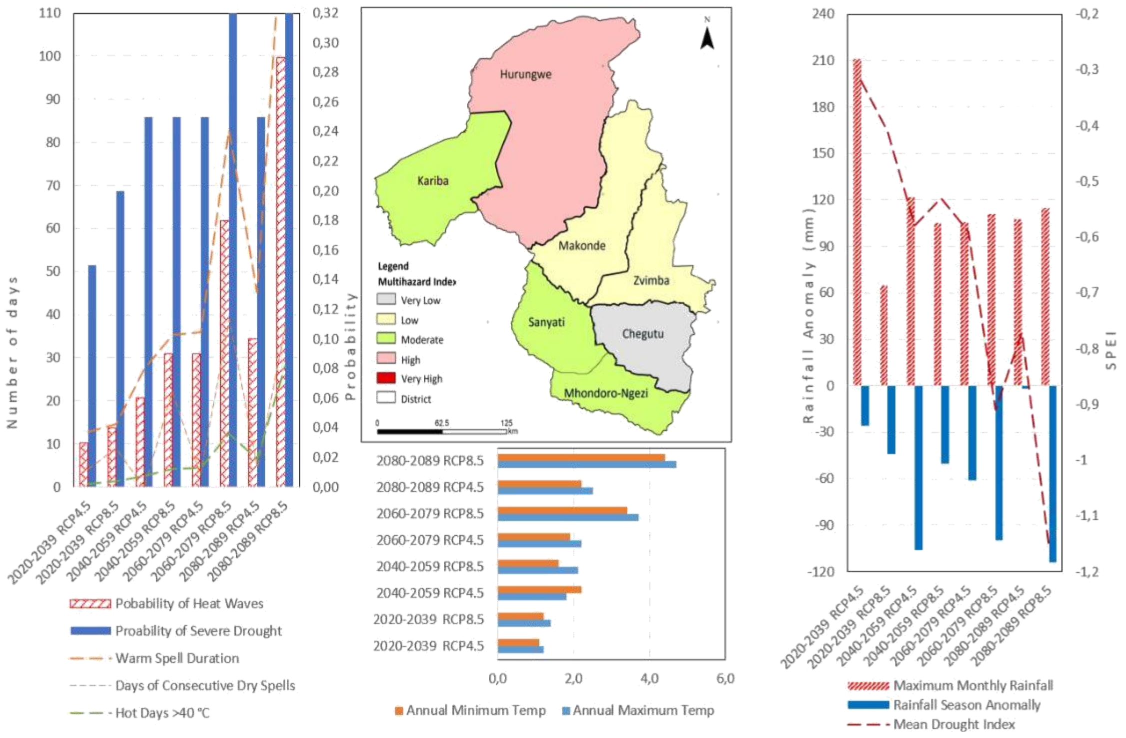


Figure 40: Projected Climate hazards and exposure to the hazards in Mashonaland West Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI.

Climate Change Impacts for Mashonaland West

Main Land Use

Recreation, wildlife management,communal areas, commerical farming areas,fishing, hydropower, sanctuary, country hot spot for ‘Big Five’ animals, Bird area, Biosphere Reserve.

Climatic Risks/Hazards

- Temperature increases more than national average
- Intensifying in drought events
- Shifts in seasonal characteristics
- Increase in extremes
- Reduction in growing season
- Increased evapotranspiration
- Lowering of water tables
- Increase forest fire risk

Settlements & infrastructure

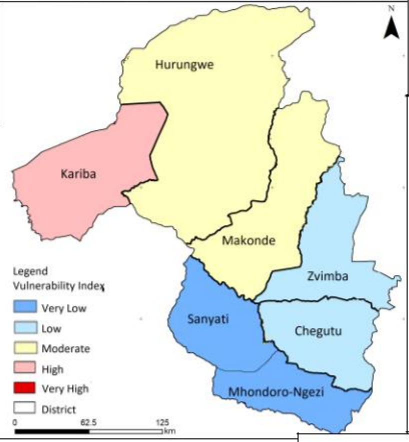
- Increasing damage risk from rock falls & landslides
- Increase in dam failure risk
- Increase in damage to roads
- Increased damage to communication & power lines
- Increase in damage to rural settlements
- Increasing damage risk from summer storms
- High demand for in-house cooling in summer and less demand in winter

Water & Energy

- Temperature rise larger than national average
- Increasing water demand for agriculture
- reduction in hydropower potential
- Increase in low or no river flow
- Reduction in hydropower generation
- Reduction in irrigation water availability
- Reduction in drinking water due to lowering of water tables
- Reduction in rainfall amounts
- Reduction in irrigation potential
- Reduction in volumes in water bodies to critical levels during the droughts and dry seasons
- Increase in energy demand for cooling

Health

- Expansion of habitats for disease vectors
- Increase in mortality from heat waves
- Reduction in comfort index
- Increase in malnutrition due to high risk of food insecurity
- Reduction in human productive power



Tourism and Recreation

- Reduction in tuorist arrivals
- Deterioration in asthetic values
- Increase in heavy precipitation events
- Increase in multiple climatic hazards
- Increased biodiversity loss reduce tourism resources
- Increased bad weather reduce attractiveness of the tourism sites

Agriculture

- Shifts in agricultural seasons
- Increase in pests and crop-animal diseases
- Increase in invasive species (lantana camara)
- Reduction in crop & animal production
- Deterioration in winter cropping conditions
- Increase in poor germination and fall start of the growing season
- Reduction in irrigation potential
- Reduction in fish species & production
- Increase in crop damage from heavy rainfall & storms
- Increase in animal mortality from heat waves
- Change away from rainfed agriculture
- Increased wildlife mortality
- Increased human wild life conflict
- Reduction in frost risk to near zero probability
- Increase in Theileriosis (popularly known as January disease) in cattle

Ecosystems & Biodiversity

- downward shift of plant and animal species
- Decrease in wetland areas
- Increasing risk of biodiversity loss
- Increasing damage risk from summer storms
- Increased forest fire risk mostly during the dry season
- Reduction in fish species & production
- High risk of species extinctions
- Increasing risk of forest pests
- Decrease in fish species

Figure 41: Projected Climate hazards and exposure to the hazards in Mashonaland West Province

3.6.9 Harare and Bulawayo Urban Provinces

The resilience of Zimbabwe’s urban provinces of Harare and Bulawayo to climate change is important since they are inhabited by almost a quarter of the population. The heat waves, which are exacerbated by urban heat island, both of which are quite recent phenomena, have been observed to also increasingly affect these urban provinces (figure 42). High soil sealing and urban sprawl in combination with more extreme precipitation events increase the risk of urban flooding. Settlements have continued to spread noticeably into areas potentially prone to river floods, thus increasing their exposure to floods. The high concentration of population, socioeconomic activities and infrastructures in low-lying urban zones make these regions and territories very vulnerable to flash flooding. Urban sprawl has increased the risk of forest fires in many residential areas over the last decades. The energy sector will be negatively affected by decreasing water availability to generate hydroelectricity and increasing energy demand for cooling, in particular in summer. In the urban environments will also face deficits on water resources, extreme weather events increased damage on structures and threats to food security, increased health risks from vector home diseases, and temperature-related morbidity.

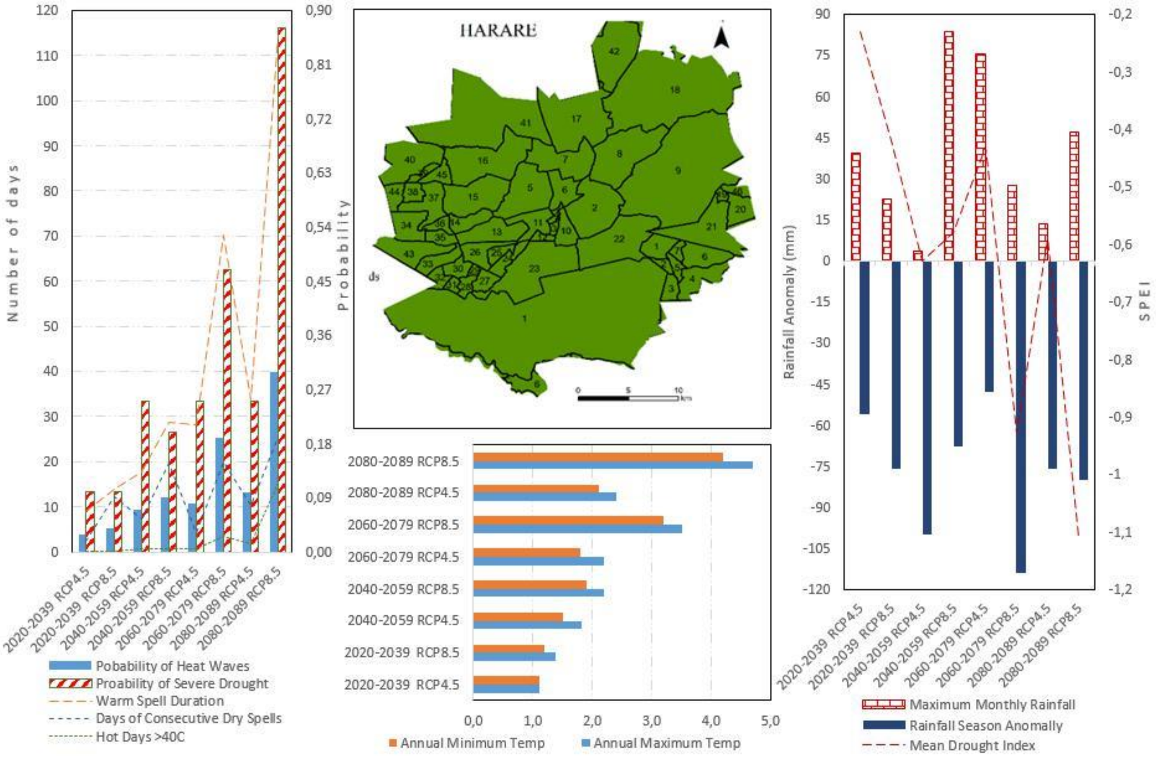


Figure 42: Projected Climate hazards and exposure to the hazards in Harare Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI.

Harare Province projected climatic variables using RCP 4.5 and RCP 8.5 for (first panel) heat waves probability, severe drought probability, warm spell duration, days of consecutive dry spells and very hot das greater than 40°C (third panel) maximum monthly rainfall, rainfall season anomaly and mean droughts indices (fourth panel) annual minimum and maximum temperature (figure 43). The second panel depicts the current climate hazard exposure for the district using a multi-hazard index.

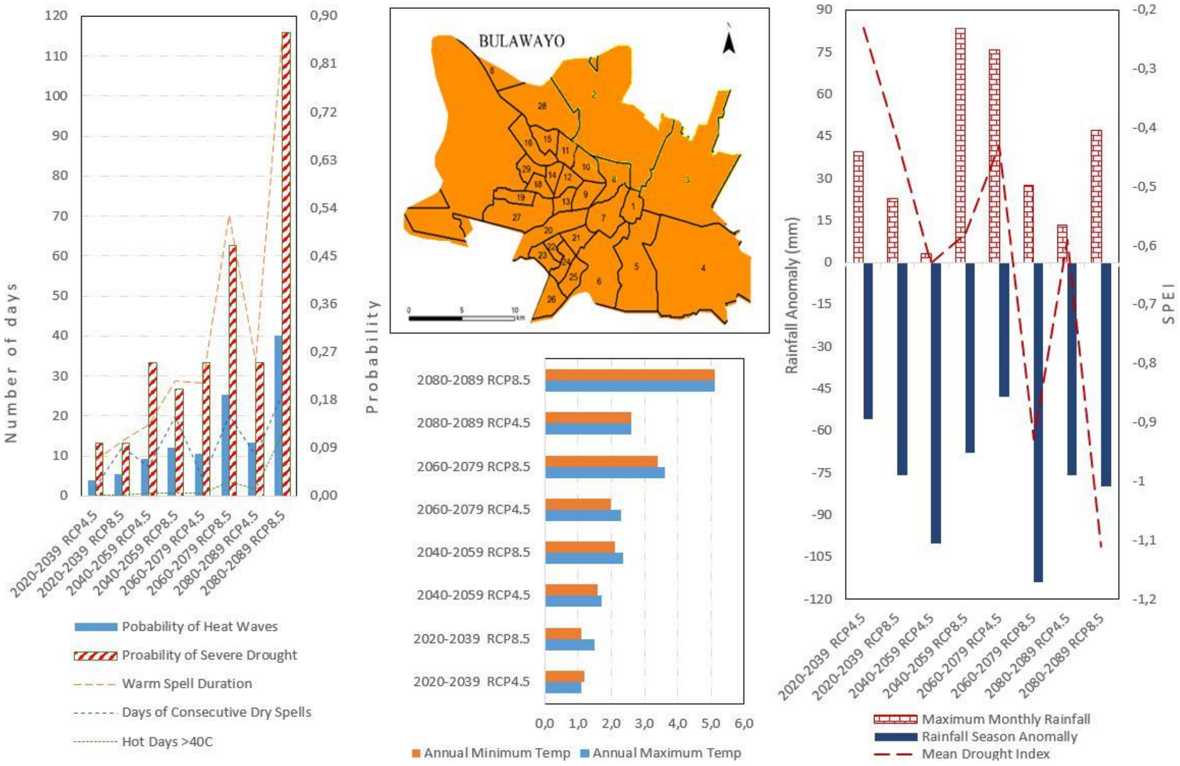


Figure 43: Projected Climate hazards and exposure to the hazards in Bulawayo Province

The graphs show the climate parameter projections under RCP 4.5 and RCP 8.5 for 2020-2039, 2040-2059, 2060-2079 and 2080-2089 time frames for (left panel) probability of heat waves, probability of severe drought, warm spell duration, days of consecutive dry spells and hot days with temperature above 40 ºC; (middle lower panel) annual minimum and maximum temperature and; (left panel) maximum monthly rainfall, seasonal rainfall anomaly and mean drought index derived from SPEI.

Bulawayo Province projected climatic variables using RCP 4.5 and RCP 8.5 for (first panel) heat waves probability, severe drought probability, warm spell duration, days of consecutive dry spells and very hot das greater than 40°C (third panel) maximum monthly rainfall, rainfall season anomaly and mean droughts indices (fourth panel) annual minimum and maximum temperature. The second panel depicts the current climate hazard exposure for the district using a multi-hazard index (Figure 43).

CHAPTER 4: DISTRICT CLIMATE CHANGE VULNERABILITY

4.1 Introduction

Identification of major drivers of district vulnerability is the first step towards targeted adaptation planning. It provides a better understanding of the sources of vulnerability in an area while informing the development of targeted adaptation. Vulnerability is multidimensional since it is driven by many factors. The vulnerability index across districts suggests that all the 59 districts of the country are to some extent vulnerable to climate risks, but some are relatively worse. Grouping districts as illustrated in table 5 helps to get a better idea of different categories of districts in the context of the vulnerability index range. This index was determined by the four dominant vulnerability indicators which were selected through principal component analysis.

4.2 Main drivers of extreme vulnerability

To adequately provide a better picture of the main drivers of district extreme vulnerability as defined by the high to very high range and low to very low range, the rest of the other 23 indicators proposed earlier were conveniently used. These indicators predominantly focused on socio-economic drivers as well as those related to primary sector-based livelihood along with some biophysical and institutional factors.

4.2.1 Main drivers of vulnerability high to very high range

The following indicators resulted in high scores for districts where they are prominent:

- Have a higher percentage of population living below the poverty line hence are mostly poor with a low per capita income with a low asset base;
- Most are in remote areas with very low and bad road network densities. Low road density has and bad roads causes poor access to markets for the purchase and sale of agricultural products;
- are mostly in region IV and V with rainfall which either does not sustain dense forest cover or had been massive deforestation;
- high composition of area with rainfed agriculture accompanied by very low irrigation potential due to very low dam water capacity hence most districts in some cases almost entirely depends on rainfed agriculture. As such the high prevalence of rainfed agriculture as one of the major drivers of vulnerability in Zimbabwe; and
- lack of forest area remains one of the major drivers of vulnerability in these districts. While in Beitbridge and Umguza it may not be biophysically possible to have a dense forest cover, in districts such as Nyanga and Gweru a higher forest cover could be achieved had it not been for rampant deforestation and soil erosion that is taking place there.

4.2.2 Main drivers of low vulnerability in relatively low to very low range districts

The districts in this range are relatively less vulnerable as adaptive capacity is higher compared to other districts (table 5 and 6). These districts are characterised by relatively low incidence of below poverty datum population, prevalence of dense forest cover due high rainfall and low deforestation rates, relatively well functioning institutions and considerable road network density. Hence unlike in relatively high-vulnerable states, here the drivers are limited. They mostly arise from:

- High proportion of well-developed irrigation infrastructure;
- Relatively low below poverty datum line population in these districts'
- Have a lot of commercial activities hence they do not depend much on natural resources for income generation; and
- Have an adaptive capacity through better functionality of institutions mostly due to high proximity to major cities who service them.

In this regard, the high to very high vulnerability of the districts imply that they require the most attention in terms of adaptation priorities whilst the other category may require reduced consideration.

Table 5: Vulnerability Index ranking of vulnerability from very low to very high categories of Zimbabwe's districts

Very Low	**Low**		**Moderate**		**High**	**Very High**
Guruve	Muzarabani	Lupane	Hurungwe	Chimanimani	Mbire	Beitbridge
Mazowe	Rushinga	Nkayi	Karoi	Bikita	Kariba	Umguza
Mudzi	Zvimba	Shurugwi	Chinhoyi	Matobo	Nyanga	Insiza
Mutoko	Chegutu	Masvingo	Bulilima	Gwanda	Tsholotsho	Hwange
Sanyati	Chikomba	Zaka	Goromonzi	Mwenezi	Bubi	Mangwe
Shamva	Mutasa	Zvishavane	Marondera	Chiredzi	Gweru	Churumanzi
Seke	Mutare	Chipinge	Makoni	Buhera	Umzingwane	
Mberengwa	Gutu	Zaka	Wedza	Mt. Darwin	Chivi	
Mhondoro-Ngezi	Murewa	Kwekwe	Makonde		Gokwe North	
	Chipinge					

Tables 6: Number of districts in each vulnerability index range for the 8 Provinces

Province	No in Very Low	No in Low	Now in Mod	No in High	No in Very High
Manicaland	0	4	3	1	0
Mash East	3	2	3	0	0
Mash West	1	2	3	1	0
Mash Central	3	2	1	1	0
Mat North	0	2	1	2	2
Mat South	0	0	3	1	3
Midlands	2	3	3	2	1
Masvingo	0	3	1	1	0
Total	9	18	18	9	6
	15.3%	30.5%	28.8%	15.3%	10.2%

4.3 Main drivers of vulnerability

4.3.1 Main drivers of vulnerability in districts of Manicaland Province

The province is characterised by periodic exposure to severe flash floods, tropical cyclones and droughts. Some districts are chacterised by high levels of poverty and a non-diversified pattern of livelihood, making them highly vulnerable to climate change. Nyanga district has the highest vulnerability index in the province (high category) values followed by Chimanimani, Buhera and Makoni who are all in the moderate range. The high sensitivity and low adaptive capacity led to relatively high vulnerability of Nyanga though the multihazard is in the moderate range. Of the dominant socioeconomic variables that were considered which contributed to this high vulnerability shown in figure 44, moderate poverty and household indices which are on the high side and the high prevalence of chronic diseases could have contributed more to this characterization. Chipinge district has very high poverty and multihazard indices but has low overall vulnerability index range. This is because the low values in dependency on rainfed agriculture due to well-developed irrigation infrastructures, low values in the child/female headed households and chronic diseases could have weighed to increases adaptive capacity of the district. Chipinge also has very high literacy rate. It is also noted that the province especially located to the northern areas, is highly dependent on natural-resource based income generation hence the lower poverty index values.

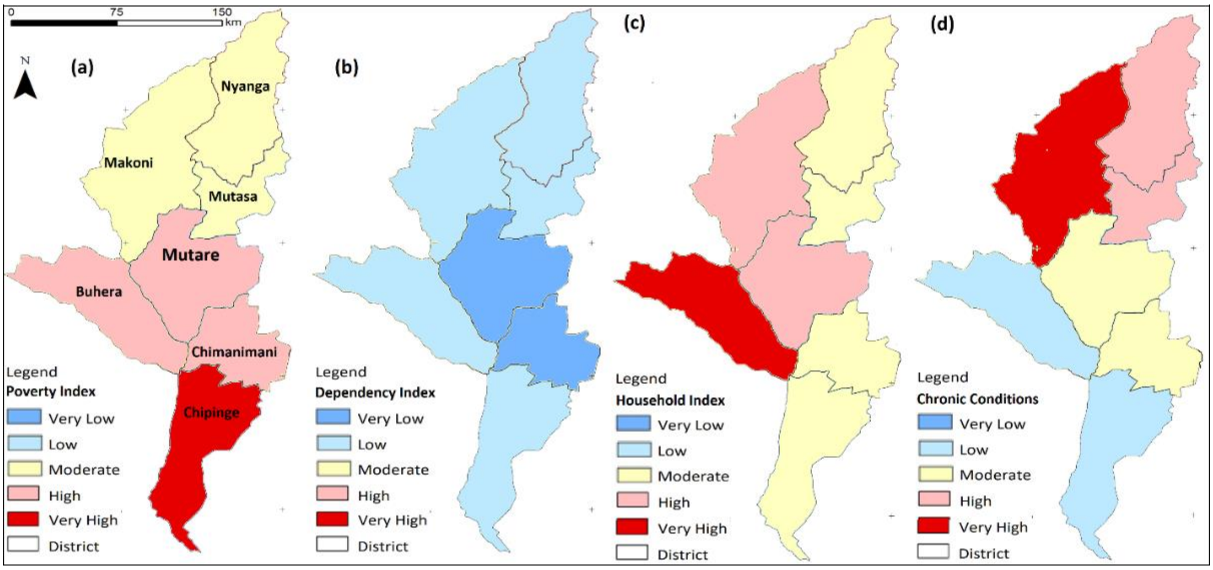


Figure 44: Spatial distribution of the four dominant drivers of vulnerability across districts of Manicaland

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Manicaland Province.

4.3.2 Main drivers of vulnerability in districts of Masvingo Province

The vulnerability index for Masvingo is high for Chivi district only but moderate to low for the rest of the districts. This is despite the observation that Mwenezi and Chiredzi had flood and drought instigated very high multihazard index with Chiredzi and Bikita having values in the high range (Figure 45). The occurrence of moderate poverty, dependence on rainfed farming and household index for Mwenezi with prevalence of chronic diseases going to a low range for Chiredzi could have resulted in the VI to be in the moderate range. Even the very high range of, dependency on rainfed agriculture for Chivi, household index for Zaka and Bikita and chronic disease prevalence for Masvingo resulted in the province having moderate to low VI values except Chivi which remained in the high range.

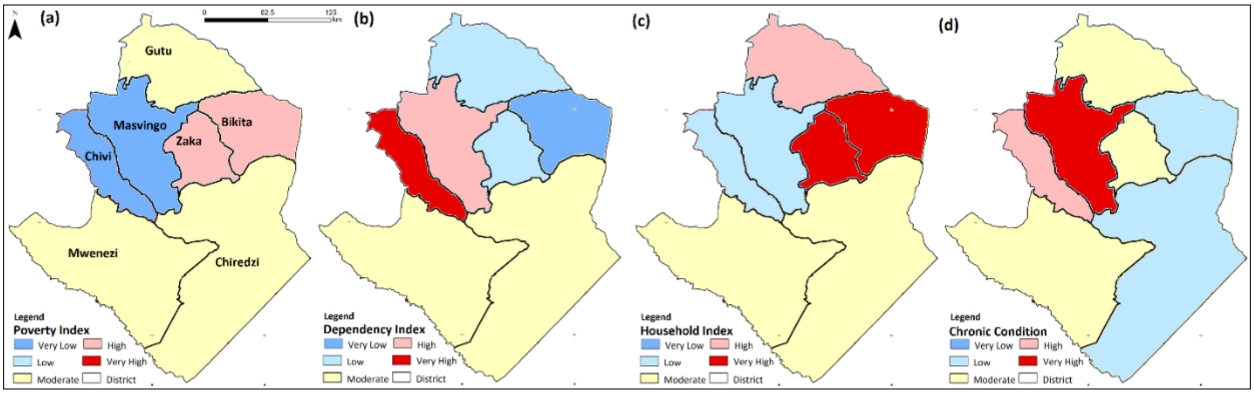


Figure 45: Spatial distribution of the four dominant drivers of vulnerability across districts of Masvingo Province

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Masvingo Province.

4.3.3 Main drivers of vulnerability in districts of Matabeleland North

The vulnerability index for Matabeleland North is very high for Hwange and Umguza but moderate to low for the rest of the districts. These very high values are mostly the two districts' very high dependency on rainfed agriculture accompanied by high values for household indices and chronic diseases. The multihazard index (related to very high values for drought and flood) seem to be performing better than the expectations were it is high only for Hwange. The low vulnerability index observed for Nkayi and Lupane are mainly due their excellent performance in dependency in rainfed agriculture, household index and chronic disease conditions. The VI for Binga was moderated by fairly good performances in household and chronic diseases indices to become moderate despite having a high range in poverty and dependency on rainfed agriculture (figure 46).

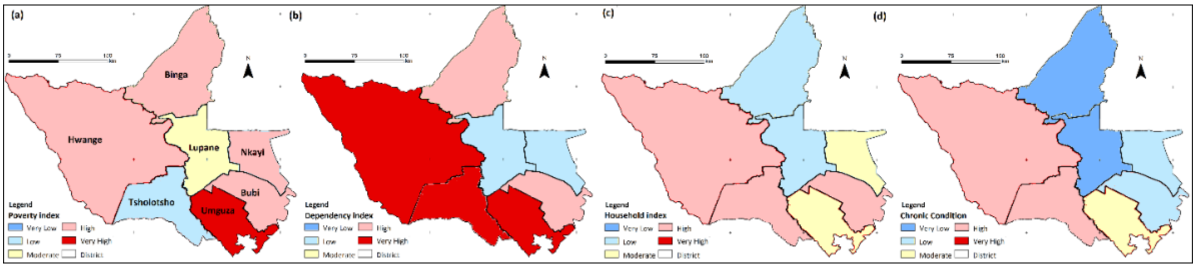


Figure 46: Spatial distribution of the four dominant drivers of vulnerability across districts of Matabeleland North

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Matabeleland North Province.

4.3.4 Main drivers of vulnerability in districts of Matabeleland South

Matabeleland South has the highest average vulnerability index across of all the provinces (table 5). The province is predominantly rural and hence agriculture and animal husbandry are the two predominant occupations of the communities. Agriculture is predominantly based on rainfed farming and irrigated farming. The province is characterised by persistent water scarcity and periodic exposure to severe flash floods and droughts along with poverty and a non-diversified pattern of livelihood, making it highly vulnerable to climate change. Since agriculture is the main source of livelihood in the province, the assessment focused particularly on agricultural vulnerability at district level. The vulnerability of the province seems to be driven by relatively high multihazard index and the high household index where the prevalence of droughts and floods are frequent and female/child headed family is high (figure 47). The province is located in the most driest part of the country and its proximity to neighbouring South Africa may have depleted families of their active age groups as they out migrate in search of better economic conditions. However, the poverty index relatively low depicting the power of remittances in alleviating the living standards of the communities. Even the dependency index on rainfed agriculture is relatively low. It appears that the proportion of the BPL population here is a lot more than the national average. As result the province has a good (though limited) prospect for building adaptive capacity to cope with the adverse climatic hazards for the large numbers of households who are child/woman headed and the very poor natural resource base in these districts.

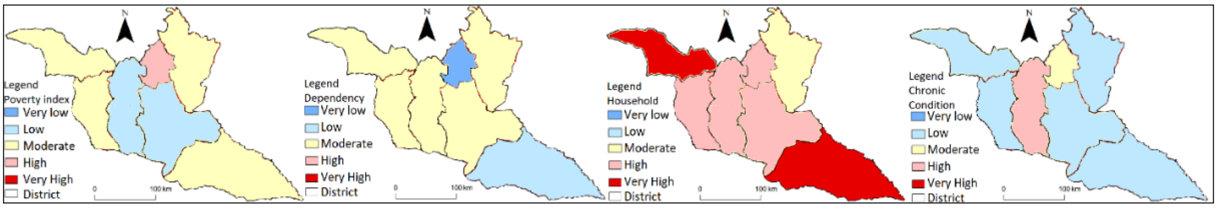


Figure 47: Spatial distribution of the four dominant drivers of vulnerability across districts of Matabeleland South Province

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Matabeleland South Province.

4.3.5 Main drivers of vulnerability in districts of Midlands Province

In the Midlands province, Churumanzi is characterised by a very high VI index value. It is followed by Gokwe North and Gweru whose VI is in the high range with the rest in the moderate and below (Figure 48). The relatively high values for Churumanzi despite very low values for its multihazard index seem to have stemmed from very high values for its poverty and dependency on rainfed agriculture. Mberengwa has the lowest VI values mainly due to scoring excellent scores the rainfed dependency, chronic disease condition and household indices. Generally the province has relatively low values in its multihazard index.

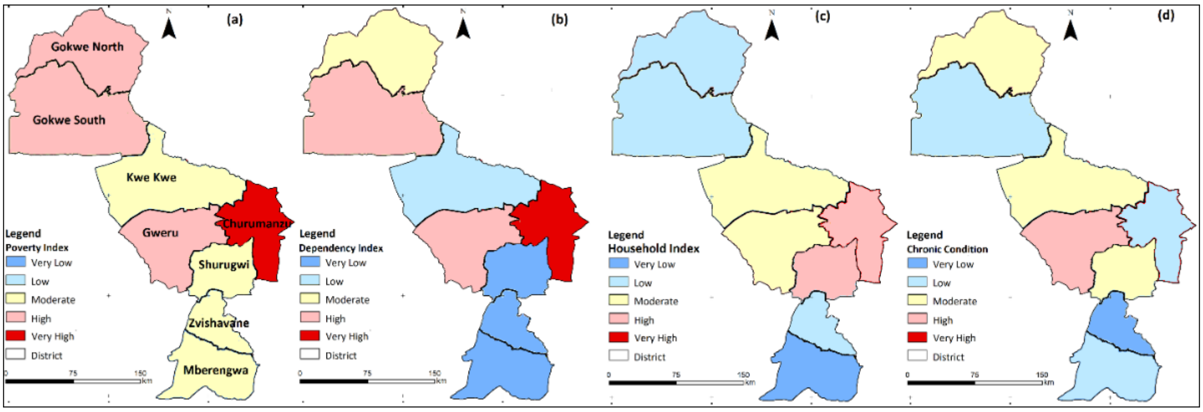


Figure 48: Spatial distribution of the four dominant drivers of vulnerability across districts of Midlands Province

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Midlands Province.

4.3.6 Main drivers of vulnerability in districts of Mashonaland East Province

In general, Mashonaland East appears has the lowest average VI of all the provinces (Figure 49). This is despite the observation that its multihazard index is relatively high values with Mudzi even being in the very high category. The dominant socioeconomic parameters particularly poverty and dependency indices were mostly enhanced by their proximity to the capital city of the country where the connection is facilitated by an excellent road network. Most of the produce that is sold at the main markets in Harare originates from these adjacent districts which have the potential to supply the market throughout the year due to their independence from rainfall.

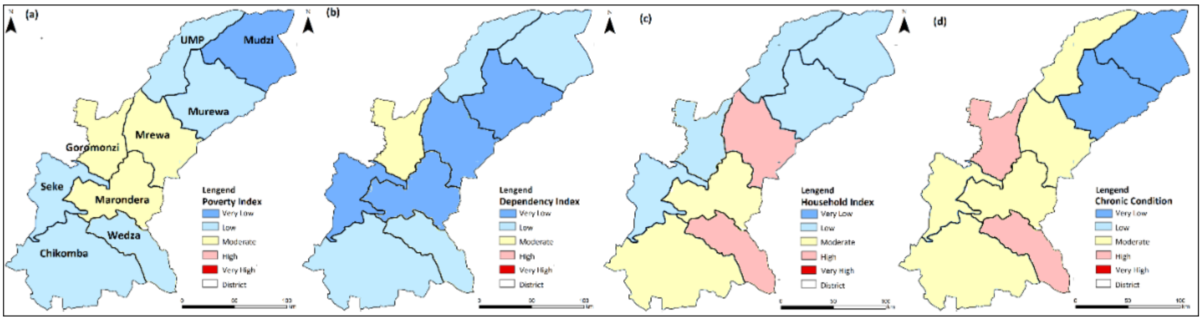


Figure 49: Spatial distribution of the four dominant drivers of vulnerability across districts of Mashonaland East province

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Mashonaland East Province.

4.3.7 Main drivers of vulnerability in districts of Mashonaland Central Province

Mashonaland Central is characterised by floods and droughts resulting in a high multihazard index (Figure 50). Most districts are characterised by a high multihazard index except for Mazowe, Bindura and Shamva whose multihazard is in the moderate low range. However, the prevalence of favourable socioeconomic conditions reduces the impact of droughts and floods, with Mbire remaining in the high range. The existence of active commercial activities such as irrigation farming and gold mining in Bindura and Shamva seems to have succeeded in moderating the VI index to relatively very low ranges (Figure 50).

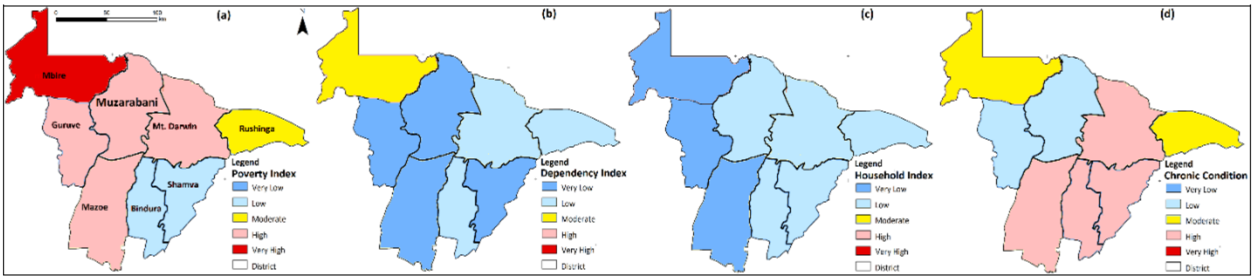


Figure 50: Spatial distribution of the four dominant drivers of vulnerability across districts of Mashonaland Central Province

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Mashonaland Central Province.

4.3.8 Main drivers of vulnerability in districts of Mashonaland West Province

Mashonaland West Province has relatively low average VI value compared to other provinces. Except for Kariba which remained in the high range even after the consideration of the socioeconomic factors on the multivariate index, the rest of the districts depict moderate to very low VI ranges. Though Sanyati and Mhondoro-Ngezi had a moderate range in the multivariate index, the VI range eventually became very low after the participation of the four dominant socioeconomic parameters depicted in figure 51.

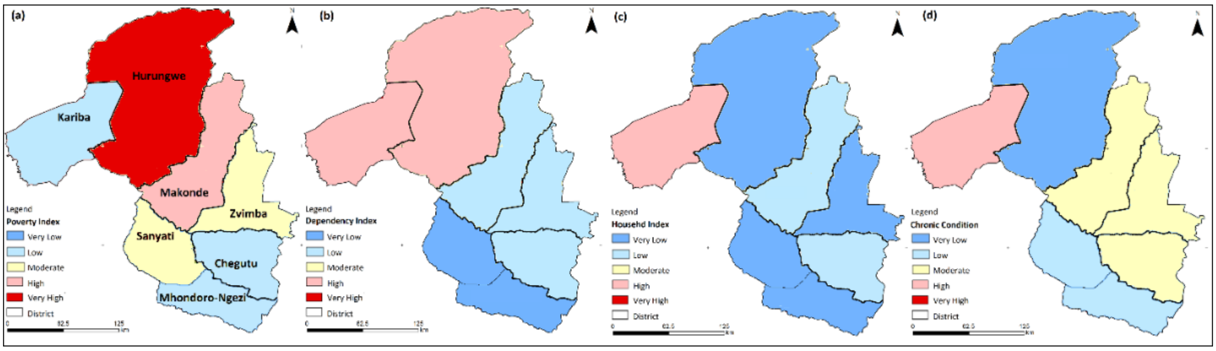


Figure 51: Spatial distribution of the four dominant drivers of vulnerability across districts of Mashonaland West Province

The panels indicate proportion of households (a) living below the poverty datum line (b) that depend solemnly on rainfed farming (c) who are female/child headed (d) with at least one member of the family with chronic diseases for districts constituting Mashonaland West Province.

4.3.9 Main drivers of vulnerability in Urban Provinces of Harare and Bulawayo

Assessing vulnerability to climate change especially for Harare and Bulawayo with population exceeding a million is important for identifying overall risks, vulnerable areas, and sectors. Though urban data to buttress the observed vulnerabilities are largely absent, this section is designed towards identifying and highlighting some of these vulnerabilities (and linkages) from an observational perspective. Climate change is evidently a risk multiplier, making existing non climatic risks more likely and more severe, thereby exposing greater communities and amenities to increased vulnerability. For example, the high prevalence of flash floods has now become the major vulnerability affecting these cities. But this heavy precipitation-driven flooding is likely to become more frequent, expansive, and deeper, thereby should be able to affect areas with no history flooding. On the other hand heat stress on human health is very likely to become more severe as more vulnerable people like the elderly and those with chronic diseases increase within the urban population. Climate change vulnerability will also increase for key infrastructure – public transportation, energy, roads and bridges, telecommunications, critical service facilities due to higher temperatures and greater precipitation-driven flooding in the near term and long term. Heat waves and poor indoor air quality will become increasingly challenging public health concerns in the near future as more people spends less time outdoors due to the expected scorching heat from the sun.

4.4 Use of district level vulnerability assessment

This chapter is aimed at policymakers and decision makers who should use it as a first step to prioritise locations for addressing climate risk at a holistic level within a vulnerability-hazard-exposure framework. This informs better-suited climate adaptation actions by factoring in differentiating features of districts and assist in the following:

- Providing baseline information for climate change adaptation planning of Zimbabwe at the district level;
- Quantifying the comparable degrees of vulnerability for all the districts in Zimbabwe before identifying the most vulnerable districts;
- Aid in the prioritization of the districts for adaptation interventions and formulating climate-resilient policies and programs;
- Inform the revision of the National Action Plan on Climate Change and other related documents;
- The prioritization of adaptation interventions and investments, for the Zimbabwe government and other international organisations like World Bank; and
- The provision of the basis to identify the entry-point of intervention for adaptation planning and investment at the district-level through the identification of priority sectors and major drivers of vulnerability.

CHAPTER 5: SECTORIAL CLIMATE CHANGE VULNERABILITY

5.1 Introduction

Zimbabwe's economy is highly dependent on climate-sensitive sectors which make it, vulnerable to climate change impacts. The projected climate change impacts are varied and hence have different dimensions. The Zimbabwe Climate Change Strategy (2014) identified six (6) priority sectors to consider for vulnerability and adaptation and these are: water, agriculture, health, energy, ecosystems and forest and tourism).

5.2 Climate change Impacts by sector

5.2.1 Water Sector

Water is a critical sector which cuts across all sectors of the economy including rural livelihoods. In the agriculture sector, water is essential for crop and livestock production. For Zimbabwe, water is also important in the generation of energy particularly hydropower energy. In this regard the availability of water in the Zambezi river is important for the economic growth of the country as the country's power is generated at Kariba. . The availability of water in the Zambezi river and Kariba dam supports fishing, recreation and tourism activities thereby generating income for the tourism industry.

River discharge has been significantly affected by climate change as some perennial rivers are now characterised by seasonal flows. Model projections indicate a general decrease for all catchments during the summer as a result of climate change. Decreasing summer flows especially in Gwayi and Mzingwane catchments will have negative impacts on ecosystems and ecosystem services (figure 52). Periods of deficient ecological water demands will increase, leading to irreversible damage to aquatic and riparian ecosystems. Settlements, agriculture and industry will likely be negatively affected by water shortages. At the same time, increasing flows in Mazowe and Save catchments will likely exacerbate existing flood events (figure 52). However, one of the most efficient adaptation measures against the combined threat of droughts and floods is water harvesting.

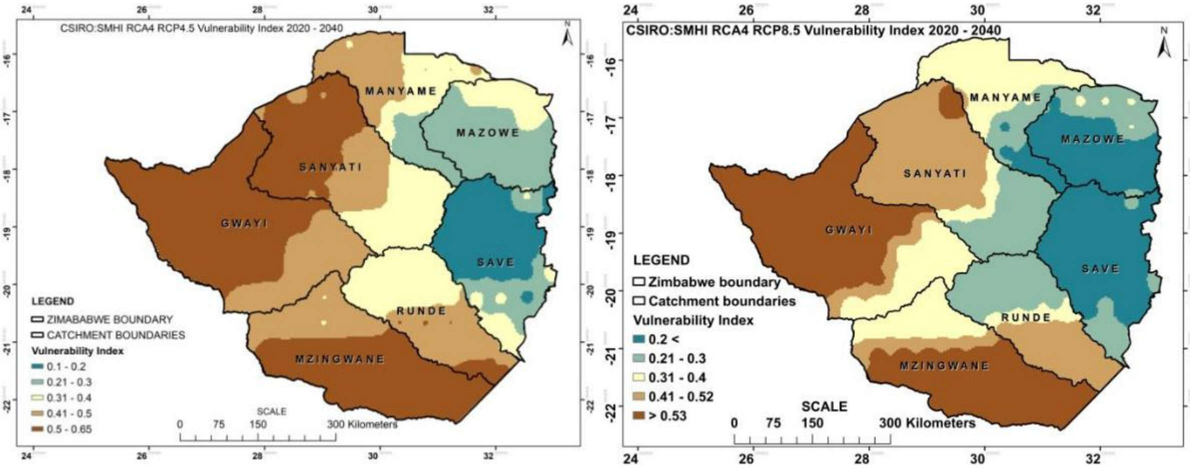


Figure 52: Current vulnerability of Water resources in Zimbabwe based on RCP 4.5 (left panel) and RCP 8.5 (right panel) for the 2040s.

Structural measures such as constructing dams, water tanks and subsurface reservoirs are other options to consider. Another promising structural measure is the installation of rainwater harvesting systems on slopes. Besides flood and low-flow control, terraces, embankments, and other structures have additional local advantages. They reduce surface erosion, counteract the desiccation of forests and cool the air thanks to the increased rate of evapotranspiration. Sub-surface water storage can also be enhanced by protecting and restoring open grasslands so more rainwater can infiltrate into the deeper soil layers than in forested areas. Growing grasslands over the catchments can also be an option as they can become primary sources of water supply for the sub-surface water resources.

The country’s total annual water generation capacity is over 23 billion m^3. This mostly comes from rainfall and runoff into rivers, streams, lakes, aquifers, reservoirs, and wetlands. The GOZ developed extensive water storage capacity prior to and after independence. The country has over 9,821 small and large dams. These dams, excluding Lake Kariba have storage capacity of about 10.6 $x10^9$ m^3 against the development potential of 47.2 $x10^9$ m^3. However, only 149 dams with storage capacity of about 8,128 $x10^6$ m^3 (~77%) are shown in Table 6 are regularly monitored by ZINWA. In this regard, the country relies significantly on its surface water resources (about 90%) whilst ground water resources contributes about 10%. Of the usage, 28% is ground water based of which 60% are from ZINWA water supply stations. Groundwater provides water to more than 70% of Zimbabwe's population although it accounts for only 10% of the available water. The highest water capacity is in Masvingo province which has more than half the national capacity followed by Mashonaland West. When the urban provinces of Harare and Bulawayo are excluded, the provinces with the least capacity are Matabeleland North and Mashonaland East (Table 7). The future vulnerability for the catchment areas is highest over the west and southern districts. This means that these areas may not be able to sustain more dams as they risk limitation in water replenishment due to the dwindling rainfall amount in future. On the other hand more dams can be built over the eastern districts as the future supply of water to fill the dams is predicted to be greater.

Table 7: Distribution of major dams by province (*source: Zimbabwe National Water Authority*)

Province	**Number of Dams**	**Net Capacity (x10^6m^3)**
Mashonaland West	14 (excluding Kariba)	1 380.0
Mashonaland East	14	120.2
Mashonaland Central	15	235.7
Manicaland	15	717.7
Midlands	20	519.8
Matabeleland North	10	85.4
Matabeleland South	27	727.5
Masvingo	30	4 322.6
Harare	2	12.4
Bulawayo	2	6.4
Total	**149**	**8 127.7**

The seven river catchments in Zimbabwe, namely Gwayi, Manyame, Mazowe, Umzingwane, Runde, Sanyati and Save have the potential mean annual runoff of 27.3 x 10^9m^3. Gwayi is the largest catchment but with the least unit mean annual runoff whilst the reverse is true for Mazowe catchment. As expected, catchments in the drier parts of the country like Gwayi, Umzingwane, Runde and Sanyati generally have lower runoff amounts whilst those situated in the wetter regions such as Mazowe, Manyame and Save have higher runoff output. Table 8 shows the annual water generation by catchment that includes information on potential storage and yield as well as the percentage that is being utilised. Currently only 25% of available yield (assuming a 10% risk of not being able to meet the demand in a given year) is utilized. Only 24% of the potential use is being utilised with the majority of the catchments using less than 21% of their potential. Hence even allowing for environmental and social water demands and considering the unsuitability of some regions for dam construction, there is still a reasonably high potential to develop further water storage in the long term where the possibility has been identified.

Table 8:.Runoff generation by catchment (*Source: MRW/ZINWA, 2007*)

Catchment	Catchment	Unit Mean Ann	Gross Mean Ann	Potential Storage(x10^6m^3)	Potential Yield(x10^6m^3)	Use

Name	Area (km^2)	Runoff (mm)	Runoff (x10^{6}m^3)	(Present Commit)	(Present Commit)	%
Gwayi	87,960	21	1,856	3.7(0.2)	0.9(98,144)	11.2
Manyame	40,497	82	3,306	6.6(2.6)	2.0(942,842)	46.6
Mazowe	34,944	131	4,582	9.2(0.3)	2.8(488.348)	17.6
Mzingwane	62,451	28	1,724	3.4(1.3)	1.2(330.329)	27.1
Runde	41,056	52	2,148	4.3(2.5)	1.2(481,259)	41.0
Sanyati	74,534	52	3,905	7.8(0.6)	2.1(430.179)	20.5
Save	48,448	126	6,094	12.2(1.2)	4.4(804.368)	18.3
TOTAL		**61**	**23.7**	**47.2(8.7)**	**14.5(3,575,476)**	**24.6**

The implications of climate change on Zimbabwe's water resources management include limited runoff for hydropower generation, increased demand within the agriculture and energy sectors, and regional differences in water supply and shortages. Specifically, warming temperatures can contribute to increased water loss through evapotranspiration and lower rainfall will negatively affect groundwater recharge and runoff. A marginal decline in mean annual precipitation could potentially lead to a significant drop in mean annual runoff and groundwater recharge. For instance, a 5% decrease in annual rainfall under a RCP 4.5 scenario is projected to cause a 17 % annual runoff decline in Mazowe catchment for the midterm and 25% in the long term.

The drier southern catchments of Gwayi, Runde and Mzingwane will be affected most, with declines in mean annual runoff of between 10% and 14% by 2050 depending on the RPC pathway. The northern catchments (e.g. Manyame and Mazowe) will be marginally affected while runoff will decline in almost all other catchments for RCP 4.5 and RCP 8.5. As such, recharge in Manyame and Mazowe catchments will be minimally affected by climate change while the Mzingwane and Runde catchments will possibly experience major declines in recharge in both 2050s and 2080s. Change in potential evapotranspiration (PET) is projected to increase for all basins across the two scenarios, ranging from 7% to 20%, with the southern catchments showing the highest changes throughout study periods. Negative impacts on groundwater will be the strongest in the southern drier catchments (e.g. Runde and Mzingwane) compared to northern catchments.

Summary

The impacts of climate change on national water resources will be diverse. For example, changes in runoff could limit hydropower generation, increasing temperatures may increase water demand for agriculture and energy generation, decreasing rainfall could increase the cost for water treatment and wastewater management. Climate change might lead to more frequent and intensified natural hazards including floods and droughts which may disrupt the manufacturing sector. For instant, increased frequency of droughts creates water scarcity that disrupts industrial processes and compromises hydroelectric power generation resulting in additional operating costs for running generators or paying more for electricity due to increased use of thermal-based sources.

In addition, groundwater recharge which is highly dependent on rainfall will be negatively affected. In fact studies demonstrate that groundwater availability is highly susceptible to droughts. These studies estimated that the percentage of population at very high risk of groundwater drought could rise from 32% to 86% if no measures are taken to adapt to the effects of climate change. This means that the country requires adequate water management strategies that take into account the sector's vulnerability to climate change. The water sector needs to identify current and future vulnerabilities and develop strategies and plans to manage water sources, basins, water supply and waste water. Large-scale irrigation projects need to be planned appropriately as adaptation measures. The current target is to have a water supply efficiency system of 8 mega litres per ha.

Table 9: Summary of the vulnerabilities and potential Impacts for the water sector

Sector	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Water Resources	*Increase in:* • air temperature • increased evaporation & evapo-transpiration • extended dry spells • frequency & severity of droughts • irregular/erratic rainfall patterns • incidents of intense rainfall • increased frequency & severity of floods • frequency cyclones & high winds • rainfall variability • heat degree days • heat waves *Decrease in:* • seasonal rainfall	*Increase in*: • variability water availability in reservoirs • rate of drying out of minor irrigation facilities • low or none flow periods in streams • depletion of ground water sources • poor drainage & water logging conditions. • rate of siltation of reservoirs • damage to irrigation, domestic & industrial water supply structures • usable water demand *Decrease of:* • agriculture production • water table • water resources • water quality due to:	*Decrease in:* • availability & quality of water for human consumption, domestic use, irrigation, electricity generation & industrial supply • decreased water quality & safety • storage capacity of reservoirs • eco-system services • sufficient water for livestock production & wildlife, and industry • loss of storage capacity of reservoirs *Increase in:* • water table depths beyond most bore holes • water loss from reservoirs due to evaporation • damage or wash away of dams

	amount & spatial distribution • rainy season length	○ sediment wash off ○ pollution of drinking water	• critical dam levels particularly during dry seasons • wastage (unutilized) of water in periods of excess rainfall • increase in damage & decline on aquatic habitat & life forms

Possible adaptation measures

As highlighted in the revised nationally determined contributions (INDC) report, a key adaptation measure in the water sector is the development and promotion of resilient water resources management. The involves implementing actions which: (i) support the use of best available hydro-climatic information to improve water resource management (water resource assessment), (ii) explore options to increase water supply from surface and underground (water demand management and water use), considering gender differences in water supply and access, and (iii) support the management of extreme events (integrated flood management, drought management). All sectors are vulnerable to climate change as a result of water scarcity. Actions under this measure are expected to increase their adaptive capacity by providing the tools and knowledge to better manage water resources and to reduce their sensitivity by increasing the availability of water. This measure is expected to contribute to achieving all SDGs. As a large number of women are responsible for collecting water for households, they lack the time and resources to focus on other income-generating activities. By improving the availability and supply of water, this measure would also benefit women directly by reducing their burden associated with fetching water, allowing them to access other productive activities. Increases in water efficiency will also bring mitigation benefits, as fewer resources would be used in water provision. Furthermore, crop and pasture productivity would increase, which would increase carbon-capture capacity through roots and residues, all other things being equal.

In addition across all sectors, there is need to enhance early warning and climate-related disaster risk reduction systems (including information management systems). This invoves taking steps to: (i) enhance early warning systems, including through better information management systems (ii) provide the systems and knowledge to manage disaster risks at national and community-level, and (ii) support the coordination of responses to climate hazards and to climate impacts across sectors and geographies.

Actions under this measure would benefit all sectors by increasing their adaptive capacity through improving knowledge of future events and improving systems to prevent, prepare for, and/or manage their consequences. Adaptation activities would reduce exposure of key vulnerable groups located in hazard-prone areas by allowing them to relocate when hazards are foreseen. This measure is expected to contribute to achieving all SDGs, except SDGs 14 and 16. Investments in disaster risk reduction would also reduce the costs of rehabilitation and reconstruction, thereby providing wider economic and social benefits

5.2.2 Agriculture Sector

The agricultural sector is climate sensitive and yet it is one the key drivers of Zimbabwe's economy. The production of food crops, cash crops, horticultural and livestock products are the mainstay of Zimbabwe's agricultural sector. The sector is mostly affected by droughts whose impacts are exacerbated by unsustainable land use practices such as deforestation, overgrazing, cultivation on steep slopes which results in land degradation. The vulnerability of the sector is also made worse by the fact that 80 % of the agricultural production is rainfed making, the sector highly vulnerable to climate change impacts. In areas supported by irrigation, there is lack of efficient water infrastructure which results in water losses worsening food insecurity and lowering household incomes. Extreme weather events undoubtedly pose serious threats to the performance of the agriculture sector and are likely to be accelerated by adverse impacts of climate change in the future. Therefore, water availability is crucial factor to agricultural development in the country. Vulnerability in this sector is exacerbated by poor farming practices and low adoption of agricultural inputs (Table 10).

Table 10: Climate Change vulnerability and its impacts on the Agriculture sector

Sector Variables	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Crops Livestock Fisheries	*Increase in:* • day & night air temperature • shorter and warmer winter season • evaporation & evapo-transpiration, • extended dry spells • frequency & severity of droughts & floods, • incidents of intense rainfall,	• Increase in: • thermal/heat stress on crops, livestock, wild animals • increased damage to crops & fields due to rainfall extreme events; • drainage & water logging • problems; • susceptibility of crops & livestock to flood & drought hazards; landslides • distribution, incidence & severity of insect pests, diseases & weeds	*Decline in:* • crop productivity & yield • wildlife productivity, • livestock assets & productivity • fish stock in reservoirs, • crop maturity period, • productivity of soils & animals • livestock feed availability & quality, • pastoral zones across the country, • animal health, growth &

	• cyclones & high winds, • Seasonal shift in rainfall & temperature regime, • Extreme events including heat waves & storms.	• shift in current production system zones • rates of runoff & soil erosion • wildlife migrations, insects, diseases & weeds • Decrease in: • water availability in reservoirs for irrigation; • soil moisture and soil quality; • adequacy of drinking water for livestock. • underground water stock & seasonal streams	reproduction, • rural livelihood • food security *Increases in:* • crop failure & diseases, • distribution of some infectious diseases in livestock, • pests pressure, • decomposition rate of organic matter , • Livestock death & crop losses. • Malnutrition incidences • Human wildlife conflicts

Possible adaptation measures

In the agriculture sector, a key adaptation measure is to develop, implement and scale-up climate smart agriculture solutions and strengthen agricultural value chains and markets. Zimbabwe will promote the use and roll-out of gender sensitive climate-smart agriculture technologies and practices such as land and water resources conservation, sustainable mechanisation, agro-ecology, water-efficient irrigation, renewable energy and energy efficiency, climate adapted crop types/varieties and livestock types/breeds, crop/livestock diversification, agro-forestry, integrated pest and disease management, post-harvest technologies, improved livestock management, fodder production and livestock feeding strategies, silvi-pastoral systems. Zimbabwe will also implement actions that focus on: (i) increasing resource-use efficiency along the agricultural value chain (ii) supporting value addition to agricultural products (iii) improving market access for women and youth farmers in remote areas, (iv) minimizing waste, and (v) reducing inequalities along agricultural value chains. Agricultural value-chains largely employ women. Implementing this measure thus requires actions that consider gender barriers to accessing information and resources (such as lack of collateral, illiteracy, etc), as well as actions that directly address gender inequalities (i.e. supporting women in accessing collateral and finance, reducing the burden of work, etc).

Actions under this measure are expected to increase adaptive capacity by providing the technology and tools necessary to increase efficiency of agricultural production. This would allow sustainable use of resources, such as water and soil in the long-term, thereby reducing sensitivity of water and ecosystems. Adaptive capacity would also be improved by providing the tools to anticipate future changes in climate and adjust production accordingly. Finally, actions would reduce sensitivity to climate change by expanding the use of climate-resilient breeds of crops and livestock. Strengthening the resilience of agricultural value chains and resource use efficiency is expected to reduce the sensitivity of water, energy, waste, and biodiversity sector to climate change and variability. Industry and commerce’s sensitivity would also decrease through increased stability of the agriculture value chain.

This measure is expected to contribute to achieving SDGs 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 13. In particular, it would reduce sensitivity of women and youth by providing them with the knowledge and skills to maintain agricultural production throughout varying climate, and to diversify their sources of income beyond production. As agricultural value-chains largely employ women, they are more at risk of unemployment when the industry is exposed. Strengthening the resilience of the agriculture industry hence contributes to reducing women’s chances of unemployment due to climate change21. Widespread adoption of climate-smart agriculture, including conservation tillage, would contribute to mitigation efforts by increasing resource-use efficiency and increasing capacity of healthier soils to capture and sequester carbon. Incorporation of legumes in crop rotations has the potential to significantly reduce nitrogen fertilizer demand and ammonium nitrate fertilizer production thus driving a corresponding reduction in nitrous oxide emissions.

5.2.3 Human health

Climate change is likely to have diverse and wide-ranging impacts on human health because climate determines the incidence and geographic range of major causes of ill health in human (Ebi et al. 2006). The changes in temperature and rainfall resulting from climate change is likely to the geographic distribution of diseases such as malaria in Zimbabwe, with previous unsuitable areas of dense human population becoming suitable for transmission (Parry et al. 2007). Food insecurity, chronic malnutrition and HIV/AIDS are likely to acerbate climate change impacts and reduce the resilience of households to climate hazards and shocks (Brown et al. 2012). Extreme weather events such as floods, droughts and heat waves are likely to affect climate related diseases such as cholera, typhoid and dysentery. Heat waves are also emerging as a key threat to human health. Zimbabwe through the Ministry of Health and Child Care has stratified the country into malaria risk zones based on current climate and control measures being implemented (figure 53).

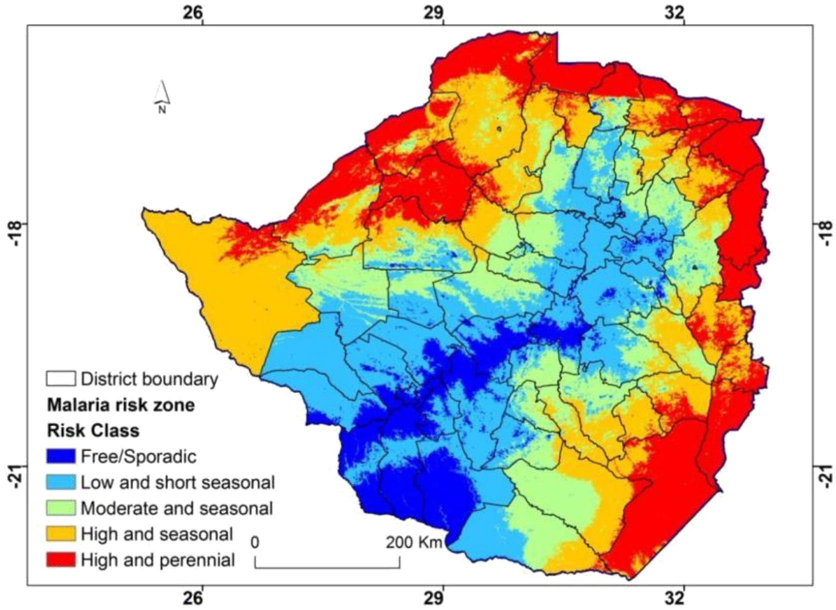


Figure 53: Spatial distribution of malaria risk based on the current climate (*Source MoHCC, 2015*)

The increase in human disease vulnerability is largely through climate change impacts on water quality, water resources, changes in habitat, increasing exposure of vulnerable groups, sanitation and drainage and vector-borne diseases. These impacts would vary in complexity, scale and directness geographically but as a function both of environment and topography and of the vulnerability of the local population. Though predominantly negative some positive impacts are anticipated. In figure 54 we present the main pathways and categories through which climate change is expected to impact on the health sector.

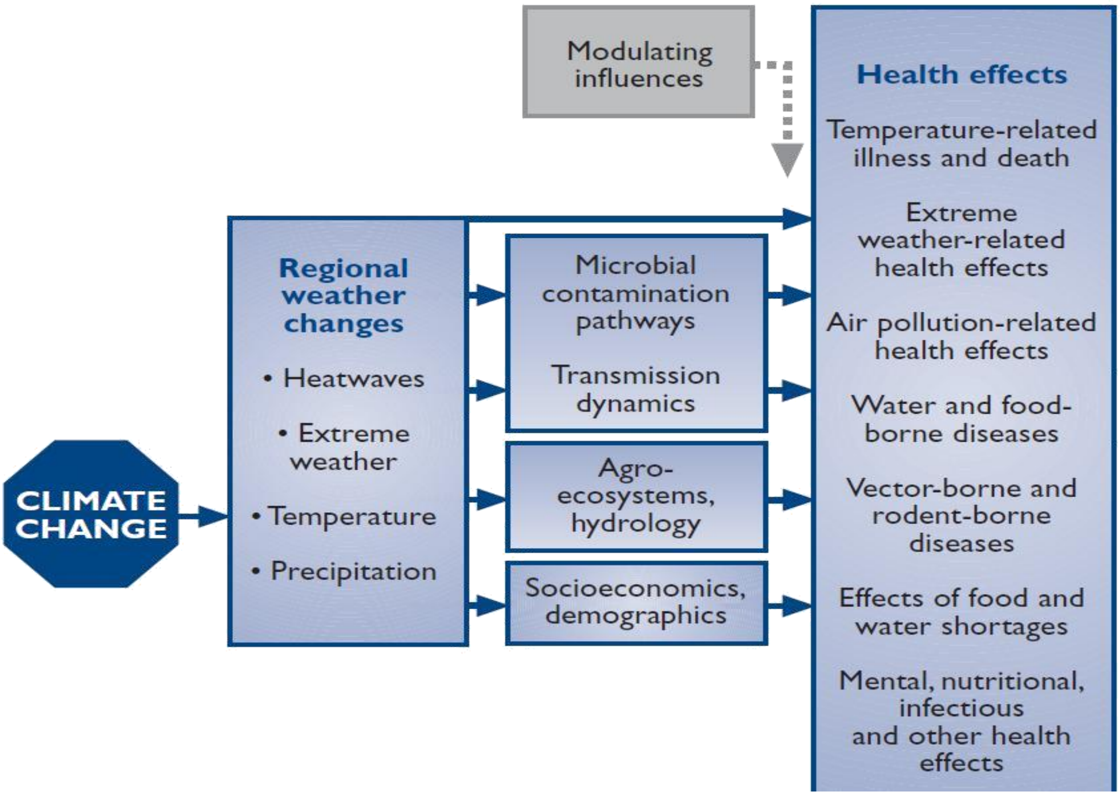


Figure 54: Pathways through which climate change is expected to impact on the Health Sector (*Source: adapted from Patz et al., 2000)*

These significant impacts of climate change on human health, suggest that climate change will reverse the recent gains Zimbabwe has achieved in malarial control, water-borne diseases, infant mortality and malnutrition. These are relatively high achievements in the health sector compared with other developing nations. However, the prevalence of COVID-19 has exposed the limitations of the country's health sector to pandemics and outbreaks. These exposed limitations and many other potential impacts require not only continued investment and focus on climate sensitive health issues, but also full integration of climate change into Zimbabwe's many existing health programmes and policies. Hence, serious effort towards adaptation against potential health hazards associated with climate change should be prioritised.

Table 11: Climate Change vulnerability and its impact to Health Sector

Sector	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Human Health	*Increase in*: • shifts in the geographic range of malaria to higher altitudes	*Increased risk of*: • spreading of existing vector borne-diseases (e.g.	*Increase in*: • mortality due to vector borne & pathogenic

(Spread & outbreaks; Heat /thermal stress)	• incidences of malaria, malnutrition, scabies & lice infestations • water-borne diseases, such as cholera, & typhoid • irregular/erratic precipitation pattern • alteration of thermal ranges for biological organisms (pests, pathogens, parasites, vectors) • boundary shift in climatic zones • frequency & severity of floods & landslides • intensity and frequency of cyclones • lightening • drought frequency and intensity • extreme events, including heat waves, and storms • concentration of dust/ soil particles in atmosphere • heat island effect	malaria) • spreading of pathogenic diseases • new areas becoming susceptible to vector bone & pathogenic diseases • new vector borne disease • outbreaks of food & water borne diseases • injuries and mortalities due to victimization to hazard events • health & sanitation problems due to poor access to water • ill health conditions due to heat stress • respiratory and eye diseases Probability for decline in cold related diseases, (e.g. influenza, common cold, COVID-19)	diseases • susceptibility to health hazards among disaster victims • mortality due to diseases and ill health conditions • vector borne diseases • water borne diseases • severe malnutrition • flood incidences & displacement • high rate of morbidity Reduced capacity of victims for productive work

5.2.4 Energy Sector

The energy sector is affected climate change. For example, the thermal stations emit greenhouse gases (GHGs) whilst the clean energy (i.e. solar, hydro and wind) generators depend on climate. Hence in high emission countries, the sector is generally considered as relevant for mitigation rather than adaptation to climate change. However, here we present it not for its contribution to mitigation but for identifying and implementing essential adaptation measures to enhance its climate resilience. Changes in temperature, precipitation, and the frequency and severity of extreme events will affect energy generation and pattern of consumption. The energy sector is the largest contributor, approximately 49%, to the country’s total GHG emissions. Though the proportions differ from year to year and season to season on average, about 60% of the national energy output is generated from non-carbon resources in the form of hydropower mostly from Lake Kariba power station. The remainder is derived from four coal power plants in Hwange, Munyati, Harare and Bulawayo. However as the population grows and industries expand, electricity demand of the country will also grow exponentially. As such, there will be increasing demand for power which increases power generation, It has already been demonstrated that most of the projected impacts of climate change will be adverse. For example, further increases in temperature and droughts whilst reducing river flow volumes in the long term for both emission scenarios is bound to limit hydropower generation as well as the availability of cooling water for thermal power generation in summer (table 12).

Summary

The following are the identified major impacts of climate change to the energy sector in Zimbabwe:

- Climate change is likely to increase electricity demand for cooling in the summer and decrease electricity generation resulting in people resorting to fossil and firewood for energy. Climate change could affect the amount of water available to generate electricity. In the southern provinces where water is already in deficit, competition for water between energy production and other uses like irrigation could increase.
- Rising temperatures, increased evaporation, and drought may increase the need for energy-intensive methods of providing drinking and irrigation water. For example demand for drinking water under hot conditions may require water to be purified and cooled before drinking using electricity. Climate change may also require irrigation water to be pumped over longer distances, particularly in dry provinces
- The expected increase in extreme events like flooding and intense storms can damage power lines and electricity distribution equipment and hence disrupt energy production. These events may also delay repair and maintenance work. Electricity outages can have serious impacts on output from industry as well.

Table 12: Climate Change vulnerability and its impact to Energy Sector

Sector Variables	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Hyro-power Thermal power	*Increase in:* • air temperature, • frequency & intensity of drought & flood events • evaporation & evapo-transpiration • dry spell lengths • irregular/erratic changes in rainfall patterns • incidents of intense rainfall	*Increase in:* • siltation rate of hydro power reservoirs • unfavourable conditions for power transportation • damage to transport infrastructure • damage to energy & industrial facilities	*Decrease in:* • capacity of hydropower reservoirs • damages to energy & industrial facilities • water that reduces the generation of energy • physical damage of dams *Increase in:* • erosion and silting on hydropower dams • upstream degradation of natural

	- frequency & intensity of tropical cyclones		resources leading to increased silting of hydropower dams

5.2.5 Human settlements and infrastructure sector

In most parts of the world infrastructure vulnerability is on the increase (Schweikert et al. 2014). Climate change is impacting negatively on infrastructure such as roads, bridges, railway lines, powerlines including human settlement such as schools and health facilities. Extreme events such as cyclone induced flooding has in the past destroyed bridges, schools, health facilities and roads in flood prone areas of Muzarabani, Chiredzi and Chipinge and Chimanimani (Mavhura and Manyena 2018). The destruction of infrastructure weakens the communities' social and economic systems. In most rural areas in Zimbabwe, roads are a lifeline for economic and agricultural livelihood including providing other indirect benefits such as access to healthcare, education, credit, political participation, etc (Fakhruddin et al. 2015).

The negative impacts of climate change reduce the lifespan of most infrastructure and increase maintenance costs. In urban areas, infrastructure such as electricity lines and poles are destroyed during extreme events such as flash floods. In rural areas the human settlements are susceptible to extreme events since they are mostly traditional dwellings made of mud and dagga which is easily destroyed during excessive rainfall events (Mudavanhu 2014). The main issue increasing the vulnerability of infrastructure to climate change is limited institutional capacity to implement large scale technology change programs that result climate proofing of infrastructure (Mudavanhu 2014). This is why infrastructure and human settlements were singled out as key pillars in the National Climate Change Response Strategy. This is meant to help review and update of policy and by-laws on building standards and codes to make them adaptive to climate change. Climate resilient rural housing model structures are already being piloted in Tsholotsho were communities that were displaced by Cyclone Dineo induced floods are being resettled.

Table 13: Climate Change vulnerability and its impact to Settlement and Infrastructure Sector

Sector	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Settlement &	*Increase in:*	*Increase in:*	*Increase in:*

Infrastructure *(rural & urban settlement)*	• air temperature • evaporation & evapo-transpiration • extended dry spells • increased frequency & severity of drought & flood events • increased concentration of dust/ soil particles in atmosphere • heat island effect • changes in established rainfall patterns • incidents of intense rainfall with thunderstorms • cyclones & high winds • land slides	• thermal stress on residents • deterioration of infrastructure facilities: e.g. thermal cracks • increased thermal stress on domestic animals including pets • increased exposure to pollutants • increased exposure to air pollution due to poor wind movements • impacts on drainage sewerage systems • accelerated deterioration of infrastructure facilities • damage to housing & settlements • damage to infrastructure facilities • decline of water quality • damages to critical social facilities: health, security, education & communication	• dependence on indoor living environments • reduction in walkability & cyclability due to unfavourable • Periodic overcrowding of the capacity of infrastructure facilities. e.g. drainage system • incidences of diseases & injury • increased demand for health & sanitation facilities • problems of supply/distribution of water • flooding of structures and settlements in low lying areas • incidences of diseases & injury • demand for health & sanitation facilities • living comfort risk • risks from collapse, declining health of buildings • loss of value, due to more frequent & heavier rain events • safety risks associated with existing buildings that do not meet standards & codes

Possible adaptation measures

There is need to ensure climate-resilient infrastructure and design. This involves implementing actions that: (i) provide the means and incentives for new infrastructure to be planned, designed, built and operated while accounting for future climate change, including extreme-weather events, and (ii) facilitate retro-fitting of previously built infrastructure to ensure it is resilient to future climate events. This measure applies to infrastructure such as buildings, roads, bridges, telecommunications infrastructure, water infrastructures like dams, sewages, drains, water supply pipes, pumps. It also includes actions that use energy generating technologies (wind, photovoltaic solar) that are not reliant on climate-sensitive hydrological resources.

Actions under this measure would reduce the climate sensitivities of all sectors that are reliant on infrastructure. Urban areas would benefit most. Urban populations would also benefit from a reduction in potential damage to infrastructure and related risks to people. Reducing the climate sensitivity of the energy sector would indirectly reduce the climate sensitivity of the many sectors that are reliant on energy supply. The co-benefits are that the measure is expected to contribute to achieving SDGs 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13. Enhancing the use of renewable energy sources would deliver mitigation benefits.

5.2.6 Ecosystems and Biodiversity

Zimbabwe is endowed with bequest diversity of biodiversity both terrestrial and aquatic and is considered among the biodiversity hotspots of the world. The rich biodiversity and various ecosystem services support human wellbeing and livelihoods. Biodiversity is primarily controlled by climate hence any changes in are likely to have a direct impact of flora and fauna diversity. The increased incidence of droughts has resulted in wetland degradation through overexploitation and expansion of human settlement. Changes in climate are providing conditions for alien species invasion and bush encroachment. In the last 30 years, hundreds of pests and pathogens have shifted their ranges towards higher altitudes with varying degrees of impact in the invaded territories. Invasive alien currently the main driver of animal species extinction globally.

Zimbabwe’s aquatic ecosystems are threatened by high pollution levels that have provided fertile ground for the spread of aquatic invasive plants such as *Pistia stratiotes* (water lettuce or Nile cabbage), *Eichhornia crassipes* (water hyacinth) and *Salvinia molesta* (*Kariba weed*). The most common invasive land plant in Zimbabwe is Lantana camara, with the highest incidences of occurrence recorded in Mashonaland Central and Midlands provinces. Another invading thorny shrub originating from South Africa known as the Cactus Rosea (*Opuntia Fulgida*) has laid siege on Matabeleland South since its first detection in 2010, making the land useless for agriculture or grazing. In the province, the total area of pasture and arable land has declined by 1%. Bush encroachment and alien species invasion are reducing livestock by degrading rangelands.

Table 14: Climate Change vulnerability and its impact to Ecosystems and Biodiversity Sector

Sector Variables	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Ecosystems & Biodiversity *(forests, wild life, wetlands & ecosystem services)*	*Increase in:* Air temperature evaporation & evapo-transpiration alteration of thermal ranges for biological organisms extended dry spells frequency & severity of oughts irregular/erratic rainfall tterns boundary shift in climatic zones incidents of intense rainfall frequency & severity of floods & cyclones	*Increase in:* • thermal/heat stress on flora & fauna • drying out of wetlands due to increased evaporation • eutrophication of water bodies & wetlands • forest die-back • migration of species due to water stress • drying out of streams • physical damages to natural ecosystems • mortality & stress on fauna *Decrease in:* • structure and composition of natural ecosystems • spatial distribution of natural vegetation	*Decline in:* • ecosystem services • loss of aesthetic value • availability of water to surrounding areas *Increase in:* • risk of migration of wildlife populations, with implications for park boundaries & human-wildlife conflict • risk of extinction of species • increased risk of wild fires due to higher temperatures

5.2.7 Tourism Sector

The tourism sector in Zimbabwe contributes 6.1% to the national GDP and employs over 90,000 people and is a significant foreign currency earner. The sector is divided into two subsectors according to functionality ie, nature tourism and culture tourism. The former is predominantly linked to the natural environment. The latter is less reliant on the weather conditions and encompasses cultural heritage and art. Thus Zimbabwe is a popular destination for tourists looking for nature's aesthetic landscapes, leisure and to explore interesting cultural sites.

The viability of sector predominantly relies on the inherent high diversity of tourism resources. There are several world renowned sites such as Mana pools, Matopos, Kariba dam and the Eastern Highlands that include the mountains of Nyanga and Chimanimani. The Eastern Highlands for example is one of the country's largest tourist attractions with its scenic environment like landscapes and ecological endowments of rich biodiversity with flagship species and ecosystems that includes most of the 400 different species of birds that reside in the country. These endemic species attract scientists and hikers from all over the world. These rely on specific resources like water volume in rivers for canoeing in the mighty

Zambezi River, river cruise, game viewing drives and trophy hunting in several wildlife centres. Victoria Falls along the Zambezi River, also locally known as Mosi-oa-Tunya commands the biggest tourist attraction in the country. The two boasts of being UNESCO World Heritage sites. In this regard, the popularity of tourist destinations is predominantly shaped by how ideal the climatic and environmental conditions are at that particular period. As such this Zimbabwe's tourism is considered a highly climate-sensitive economic sector similar to for example agriculture and energy where the changing climate is a principal resource.

Table 15: Climate Change vulnerability and its impact to Tourism and Recreation Sector

Sector	**Climate Hazards**	**Vulnerabilities**	**Potential Impacts**
Tourism & Recreation *(Tourism & bio-diversity, & cultural assets)*	Increased in: • air temperature • extended dry spells • frequency & severity of drought & flood events • irregular/erratic rainfall patterns • frequency & severity of Cyclones and high winds • land slides	Increase in: • degradation of natural ecosystems & biodiversity • drying out of wetlands • eutrophication of water bodies & wetlands • forest die-back • drying out of streams • destruction of riverine ecosystems • loss of recreational areas • damages to monuments & archaeological assets • creation of unsuitable conditions for recreation & travelling • increased incidents of disaster situations	Decline in: • scenic attractions & aesthetic value • cultural assets • recreational activities & opportunities • access due to damaged roads and infrastructure Increase in: • emergencies in travelling • tourist facilities affected by reduced availability of water & increased temperatures. • adverse impacts on ecologically-sensitive tourist destinations • potential for migration of wildlife populations • potential for species extinction • damages to tourism infrastructure

CHAPTER 6: CONCUSIONS AND RECOMMENDATIONS

The vulnerability assessment presented in this report was based on detailed literature review and historical data from different sources including interviews with key stakeholders. Both climatic and non-climatic factors were considered in assessing the vulnerability first at province down to district level and later for of key sectors (i.e., agriculture, water resources, public health, tourism & recreation, energy, settlements and infrastructure, and ecosystems & biodiversity). When considered in the holistic sense, the change from current to future climate exposure was unfavourable. Of note is the observed increase in the frequency and severity of extreme weather events. A series of major droughts, especially in the recent decades has been the major natural hazard to affect the country especially her GDP growth which is severely impacted on each occurrence of a major drought. Of note is that the number of total people affected and economic losses caused by droughts have been observed to increase exponentially in recent years. These magnitude of drought have been intensified by increased extreme temperatures and dry spells with significant deterioration of the agricultural season through the amplification of the unreliability of the onset and secession of the rainfall season accompanied by enhanced concentration of heavy falls in a few rainfall episodes. The country is extremely prone to riverine floods which is mostly tropical cyclone induced which track in the westward direction from the Mozambique Chanel. While droughts and floods are strongly associated with total economic loss, epidemic diseases, particularly bacterial and parasitic types, contribute to significant portion of total deaths and total affected by natural disasters.

In this report, data used for was downloaded from the World Bank website *https://climateknowledgeportal.worldbank.org/country/zimbabwe/vulnerability)* The results indicate that the likelihood of the country encountering severe drought is projected by model ensemble models to increase by 21% in 2040 – 2059 and 47% in 2080 – 2099 compared to baseline period of 1986 – 2005 under RCP8.5 scenario. The severity is more pronounced over the southern and western parts of the country. Maximum temperatures are set to rise with the number of days with maximum temperature above 35°C is expected to increase by 39 days in 2040 to 2059, and 108 days in 2080 to 2099 from the reference period (1986 - 2005) under RCP8.5. At the same time, the change in days of consecutive dry spell annually is projected to increase by 13 days in 2040 – 2059 and 25 days in 2080 – 2099. As such extreme temperatures and precipitation reduction through increased intensity and frequency of dry spells will be more prominent in the country resulting in more intensified drought conditions and crop failure. Consequently, more frequent epidemic episodes, with potential for enormous social and economic loss across multiple sectors including those prioritized by the government (e.g. Agriculture, Water, Energy, Forestry, Tourism), are highly possible.

Several sources of data were used to analyse the sensitivity and adaptive capacity at district level to come up with the adaptive capacity of the national provinces and their districts. The purpose was to measure the comparable degrees of vulnerability for all Zimbabwe districts for prioritization of the districts for climate change adaptation planning and investment. It was noted that the districts of Matabeleland South and North districts had the worst VI values whilst Mashonaland East and Central districts had the lowest VI magnitudes. The major drivers of vulnerability for these districts were attributed to suitability for rainfed agriculture as they appear to be highly correlated to the average ranking of the agro-ecological regions classification.

However, it should be noted that vulnerability is a relative measure. The depiction of the position of one spatial unit with respect to the other relatively low vulnerability doesn’t necessarily imply that the spatial unit has low vulnerability in an absolute sense. Based on the derived VIs, we are able to safely conclude in this report that all districts in Zimbabwe are to some extent, vulnerable to climate risks. Since the ranking of the district vulnerabilities by using a VI indicates the relative vulnerability of the districts hence provinces, our assessment can assist policymakers and funding agencies to prioritize districts for adaptation interventions. In addition, by documenting the differentiation in the relative vulnerability of the national districts, the corresponding response by various stakeholders should ideally be differentiated as well. This essentially implies that in districts with high vulnerability, the adaptation action should in fact, focus on decreasing vulnerability. On the other hand, in districts that are relatively less vulnerable, the adaptation actions should be geared towards managing climate-induced hazards and exposure to these hazards. Consequently, such a targeted approach would help in enhancing the efficiency and effectiveness of adaptation actions. Due to scarcity of observed data on these economic sectors, it could be sufficient to base the adaptation options on this information.

Lastly, adopting the approach of differentiating vulnerability of districts would assist in the following:

- Ranking and identification of the most vulnerable provinces and districts so as to inform on the prioritization during adaptation planning and investments;
- Provide a basis to identify the entry-point of intervention for adaptation planning and investment at the district-level through the identification of priority sectors and major drivers of vulnerability;
- The information could be critical for developing adaptation projects for the Green Climate Fund, Adaptation Fund, and funds from multilateral and bilateral agencies, etc;
- Can be used to facilitate Nationally Determined Contributions, which aims to adapt better to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly the prioritized sectors and can also aid to plan disaster management and;
- Finally, this report may contribute to reporting under the Paris Agreement, Article-9 through the assessment of climate change impacts and vulnerability; the formulation and implementation of a National Adaptation Plan, monitoring and evaluation of adaptation plans, policies and programmes; and the development and implementation of resilience of socioeconomic and ecological systems.

A vulnerability assessment is inherently a data intensive process and hence non-availability of the latest data remained a major challenge, as observed for a number of districts. Lack of availability of data, in many cases, had both spatial as well as temporal dimension that compromised the results to some extent. As such, besides the current covid-19 pandemic limitations, there is need of a strategy for data generation for a climate-change risk and vulnerability assessment and adaptation planning down to the ward/village level. This is because the generation of data on important indicators and risk assessment is important. However, in spite of these data availability challenges, the current effort is first of its kind where vulnerability assessment based on a common framework for all the districts in Zimbabwe have been done. Doing the exercise has been essential as it helps to understand climate risks and provides information, on the location specific measures to be taken to adapt to climate change. As such it becomes the first step in informing adaptation planning where policymakers of Zimbabwe are presented with vulnerability profiles of different districts using a common assessment framework. The framework is based on the IPCC 2014 ‘Risk and Vulnerability Framework’ which is now in use and is a clear improvement over the IPCC-2007 framework. Consequently, there is need to objectively identify adaptation options that address the needs of the affected communities and this report specifically provides for such a bias which can be successfully exploited.

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Annex I. Approved vulnerability variables, data sources and expert weights.

Dimension	**Indicator/Variable**	**Code**	**Impact Direction**	**Data Source**	**Expert Weight***
Economic	Food insecure pop (%)	FOODINSE	+	ZimVAC Report, 2019/2020	1.0
Economic	Cereal insecurity prevalence (%)	CEREAINSE	+	ZimVAC Report, 2019/2020	1.0
Economic	Poverty prevalence (%)	POVPREVA	+	PICES Report, 2017	1.0
Economic	Extreme poverty	EXTPOVER	+	PICES Report, 2017	1.0
Economic	Poverty gap index	POVERGAP	+	PICES Report, 2017	1.0
Economic	Poverty severity index	POVERSEV	+	PICES Report, 2017	1.0
Economic	Pop without permanent jobs (%)	NOPEMJOB	+	PICES Report, 2017	1.0
Economic	Labour force in agriculture (% of total population)	LABAGRIC	+	PICES Report, 2017	0.6
Economic	Livestock (cattle) mortality (%)	CATMORT	+	ZimVAC Report, 2019/2020	1.0
Social	Illiteracy rate (%)	ILLITR	+	ZIMSTAT	1.0
Social	Stunting levels	STUNTN	+	ZimVAC Report, 2019/2020	0.5
Social	Global Acute Malnutrition (%)	GAM	+	ZimVAC Report, 2019/2020	0.5
Social	% of pop living with disabilities	DISABILIT	+	ZIMSTAT	0.1
Social	HIV Prevalence or pop with ill health or chronic condition (%)	HIVPPREVA	+	ZimVAC Report, 2019/2020	0.2
Social	Rural population (% of total population)	RURALPOP	+	ZIMSTAT	0.7
Social	Households with poor food consumption patterns	PATTERNS	+	ZimVAC Report, 2019/2020	0.6
Social	Gender equality (female-headed households, %)	HHFEMAL	+	ZIMSTAT	0.3
Social	% pop receiving food aid	FOODAID	-	ZIMSTAT	0.9
Social	Social dependency (dependency ratio, % of population <15 and >64 years old,	SOCIADEP	+	ZIMSTAT	0.1
Social	Child-headed households, %)	HHCHILD	+	ZIMSTAT	0.9
Infrastructure	Population without access to (improved) sanitation (%)	SANITA	+	ZimVAC Report, 2019/2020	0.1
Infrastructure	Population without access to clean/safe drinking water (%)	WATER	+	ZimVAC Report, 2019/2020	0.6

NB: +(ve) means increase and –(ve) decreases; ***** 1 indicates the highest relevance according to expert judgement, whereas 0 means no relevance.